COMMUNICATIONS SYSTEMS TEST PROCEDURES

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THESIS

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ABSTRACT

Several recent studies of Naval Communications have determined that the system is not operating properly. This paper presents a test procedure which will improve the performance of the equipment that composes the Communications System. The need for a test procedure, modes of failure and present test procedures are examined. It is determined that present test procedures referred to as system level tests are mislabelled and are actually subsystems level tests. A Systems Level Test, the Standard Measurement Technique (SMT) which applies inputs of known degradation to a system and quantifies the output is presented. Present problems and potential applications of SMT are discussed.

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I. COMMUNICATIONS AVAILABILITY AND THE NEED FOR A SYSTEM TEST PROCEDURE

In recent years several studies of the Naval Communications System have been conducted such as the Base Line II, (1), 1966, Rope Eval exercise, 1971, (2) Mollohan report, 1972, (3) and the CNO's Industrial Advisory Committee on Telecommunications (CIACT), 1972, (4). It is not the intent of this paper to restate the studies which have been made but rather to show how these studies support the need of a communications system test procedure which will perform better than our present subsystem level tests.

Many of the deficiencies uncovered during one study (which is classified and cannot be identified in order to keep this paper unclassified), were attributable to the fact that an adequate method of determining and monitoring a Communication System's Performance was not available. The inability to locate the cause of the failure or degradation would very often result in placing the blame on the other station (s) or on the atmosphere. An element of Black Magic was introduced because neither end of the trunk knew where to assign the blame, (itself, the other station or the atmosphere). There was no method available to determine the system's level of performance. There are standards available by which to measure component, equipment and subsystem performance but there are no standards to measure the overall performance of a system either shipboard or shore station. The Report said

there is a need to prepare and publish detailed standard procedures for operations, maintenance and management of Naval Communications on a systems level. The Report also pointed out that the "systems approach" is not used or taught at any level of the Naval training establishment.

The studies mentioned have attempted to measure the Naval Communications System's ability to communicate and the conclusions are that the system is a very poor performer. It takes too much time, uses too many assets, looses messages and, occasionally, ceases to function.

The CIACT report called upon the Navy to develop an overall plan to include a general performance description for the total Naval Communications system [4, p. 17]. It can easily be argued, that some means must be available to measure the "general system performance" or the "description" is of little value. This implies the need for a system test procedure. The CIACT goes on to say the Naval Communications Command is not allowed billets for communications/electronics engineers to operate, service and manage a complex communications system. With no person ready or trained to manage a communications system, system accountability was not called for, therefore, there was no test of the system in order to measure it.

Now that official attention has been drawn to the need of a system test procedure to measure the level of performance of the system, an attempt will be made to specify what the system test procedure should accomplish.

The test procedure should be able to determine if the total system is operating and if so, at what level. No system will operate continuously at 100% and if System A is operating in a degraded mode, will it be able to communicate with System B which is also operating in a degraded mode? How much degradation can the entire system accept and still perform satisfactorily? The test procedure must be able to determine how much degradation (either in the input signal, or within itself), a system can tolerate. The test procedure should be able to predict the system availability so that the user can plan the execution of this assigned mission.

NASA has established long-term average system performance goals for the various transmission media (microwave, land line, submarine cable, communications satellite, and HF radio).

NASA circuit availability objectives expressed on percentages, indicating the portion of the total scheduled operating time during which the circuit is expected to be available.

Microwave and landlines	99.5%
Submarine cables	99.5%
Communications Satellite	99.8%
High-frequency radio	95.0%

Table 1-1 NASA circuit availability; adapted from Stelter [5, p. 274]

These goals, in principle what the CIACT report calls for, are expressed as percentages, indicating the portion of the total scheduled operating time during which the circuit is expected to be available to the user. "Circuit" as used here

includes the medium of transmission and the equipment at both ends; a trunk. NASA measures its circuit performance by subjecting it to a bit error rate test of 24 hours duration on a periodic schedule. A Data Transmission Test Set generates a 2047 bit pseudo random pattern that is transmitted via the modems normally associated with a particular circuit, to a compatible receiver. The receiver is attached to a Print-Punch recorder. This recorder provides a time-tagged, permanent record of the circuit measured bit error rate. In this manner a circuit level of performance is established [5, p. 272].

Compiling circuit performance levels enables NASA to establish a system level of performance.

A Naval Underwater System Center study has proposed a similar test procedure. The test is made by applying an input sequence X such that the resulting output sequence will be Z if, and only if, the circuit is operating correctly. In this manner a detailed knowledge of the logic elements, the mechanics, the theory and their interaction used to implement the system is not necessary in order to test it. The test will detect almost all malfunctions resulting from single, simultaneous or unanticipated failures. [6, p. 4].

The final report on Evaluation of the Unencrypted Data Link System of the P-3C airplane (INSERV REPORT) brings out the need for a system test procedure which can isolate fault to a component. It criticizes the AN/ACQ-5 built-in test equipment which isolates faults to a group of modules or subsystems which can contain up to 46 components. [7, p. 23]

The test procedure should be able to locate the cause of the degradation or failure down to the component or piece of equipment level in order to ensure maintainability and high system availability.

In summation, the Communications System test procedure should be able to accomplish the following:

1) Detect any significant malfunction.
2) Quantify the level of performance or determine the level of degration at which the system is operating.
3) Determine how much degradation in the input signal a system can tolerate and still perform satisfactorily.
4) Locate the cause of the malfunction down to the component piece of equipment level.
5) Aid in improving system maintainability.

A test procedure which attempts to satisfy these criteria is presented in this paper. Following chapters will attempt to show why a test procedure is needed, what a test should measure and how various present test procedures compare.

II. A STUDY OF AVAILABILITY

The ultimate goal of any system or equipment is to fulfill the particular mission for which it was designed. Before any system or equipment can fulfill its mission, it must be available. Increased equipment complexity, new performance requirements, and extreme environments have resulted in higher failure rates, greater requirements for maintenance and lower availability of current systems. [8, p. 117]. There has been a steady improvement in component reliability, but at a slower rate than the increase in complexity. So systems and equipment reliability has fallen to the point where the system often is not available to the user when and where it is required. Furthermore, the systems and equipment are so expensive that it is no longer practical to get around this problem by buying more systems than are needed. The operators have come to realize that the systems they have, must be available if they are to fulfill their particular mission. [9, p. 12-1].

In the 50's and early 60's system availability was synonymous with reliability. The prevailing attitude was that if enough reliability could be built into a system its corresponding availability would ensure system effectiveness. This attitude was fostered by NASA because it determined that in space work there would be no means to replace or maintain any system which had failed. NASA utilized redundancy of critical components to attain the needed level of reliability.

Therefore reliability was equal to availability and all of the literature of the period stresses this point. As systems engineers have learned to understand and work with reliability they have realized that the initial premise is true but that systems availability could be obtained by means other than reliability such as maintainability.

It must be recognized that systems availability not reliability is the ultimate criteria and that it can be obtained through reliability and maintainability. This criteria can be expressed mathematically as the relationship between availability A, reliability; mean time between failure (MTBF) and maintainability; mean time to repair (MTTR). [10, p. 8-11]:

$$A = \frac{MTBF}{MTBF + MTTR}$$

This paper supports that premise and will attempt to show that adequate testing is needed to support maintainability in order to achieve availability. (Fig. 2-1)

A. RELIABILITY

Today, although in an environment of declining "technology spending", especially related to defense and aerospace, emphasis is focused on operational and system effectiveness. Austerity in spending, coupled with the need for more sophisticated equipment, focuses an even more important light on the need for a new and more practical reliability engineering technology. The continued criticality of effective equipment performance in sophisticated systems creates a changing emphasis on reliability

and requires much more careful control of the design process. [11, p. 7-1].

Reliability definition: 1) The ability of an item to perform a required function under stated conditions for a stated period of time. 2) The characteristics of an item expressed by the probability that it will perform a required function under stated conditions for a stated period of time [12, p. 198]. This general definition is just a starting point; the product specification for each product should include clear definitions of all modes of operation important to the function of the device. Dormant and operating environments as well as life expectancy are necessary considerations in the specification.

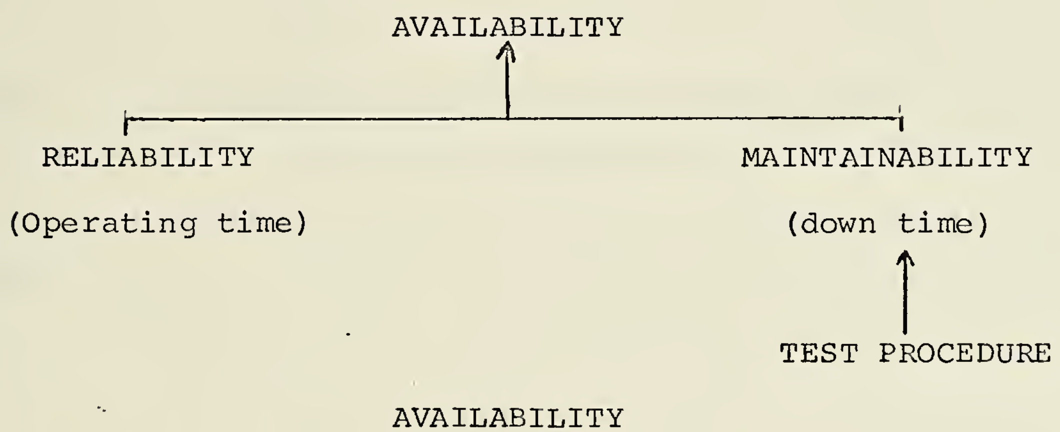
A satisfactory definition of reliability in the product specification should provide all the information necessary to judge whether device operation is proper or improper. The definition should state what constitutes failure and the conditions under which failure occurs. Reliability is usually stated as the "mean time between failure" - MTBF along with a confidence interval on the mean time.

In order to ensure that a system has the required reliability, DOD has found it necessary to establish a formal, four phase, system life cycle. The system consists of Concept Formulation, Contract Definition, Acquisition and Operational phases.

In the Concept Formulation phase, the mission of the system is justified and its long range goals are stated. The mission

is defined as reliability requirements predictions are made on the basis of the functions that must be performed to accomplish system effectiveness and mission successes. The accuracy of these predicted requirements need only be enough to justify proceeding with the next phase of the project. Alternative solutions are listed and feasibility studies may be conducted.

The Contract Definition phase includes identification and specification of system characteristics and the preparation of program plans which will assure a high probability of achieving the specified missions in a cost effective manner. Modern program management demands that specification



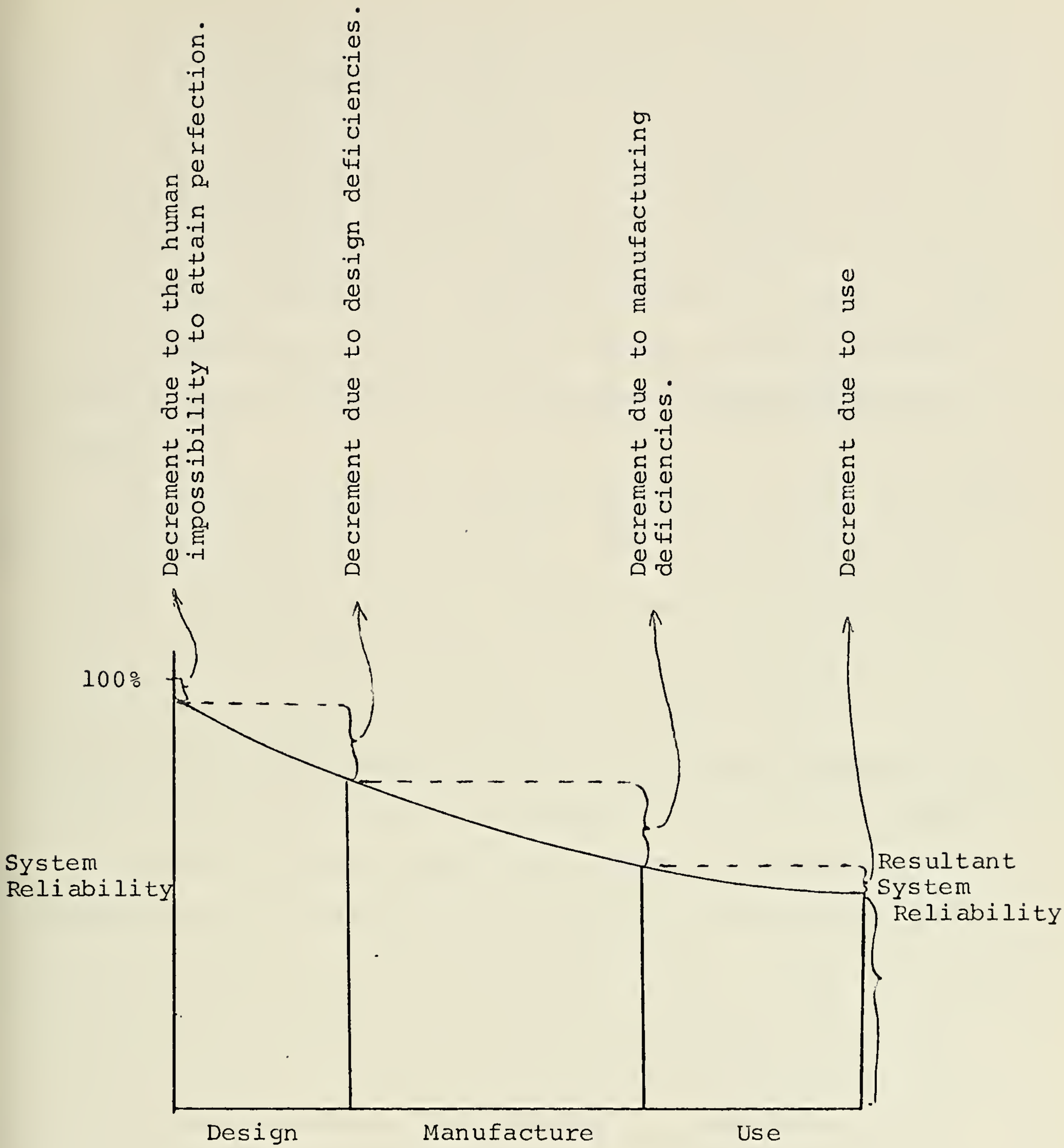
- Adapted from Blanchard [8, p. 18]

(Fig. 2 - 1)

decisions be based on quantitative analysis. Numerical values for the system characteristics, i.e., reliability, maintainability, operability, safety, cost analysis, quality, security, training, procedures and logistics, must be predicted

during the Definition phase of the system life cycle. Reliability and maintainability program plans must be part of a total management system. Identification and funding of reliability and maintainability programs must be an integral part of a program managers overall cost, schedule and technical control system. [13, p. 1-5]. These characteristics must be repredicted or assessed repeatedly throughout the Acquisition phase and they must be measured or demonstrated before and during the Operational phase. These numerical values have value only when used to give a predicted, assessed or measured value of overall system effectiveness.

While determining a quantitative reliability specification, certain factors must be kept in mind. It is impossible for man to build a system with 100% reliability because of the limits of knowledge, physical laws and monetary constraints. There will be a reliability decrement due to design deficiencies, manufacturing deficiencies and use. (Fig. 2-2) These losses will occur. In addition to the physical environment problem the effect of the social environment containing people, the man/machine interface, and their expectations, goals, motivations, training, and other psychological and physiological attributes will introduce some variance to the stated reliability. [15, p. 255]. The system planners must determine how much reliability loss can be expected and how much can be tolerated. There are numerous mathematical methods of quantifying the reliability necessary for a particular system. Such as Monte Carlo models [16, p. 4) and regression analysis.



System Reliability

Adapted from Landers [14, p. 26]

Figure 2 - 2

An additional input needed before a level of reliability sought can be selected is cost. It must be recognized that there is a cost effective level of reliability and that any demand for greater reliability will be disproportionate with its cost. Above this point some means to achieve increased availability other than reliability should be sought. Trade-offs between cost, availability, reliability and maintainability must be analyzed to determine the cost effective blend.

With quantitatively designed reliability values available manufacturing can be monitored to ensure attainment of the needed reliability levels. Emphasis must be placed on the fact that the reliability goals are determined prior to manufacturing and are included in the specifications. In this manner all personnel working on, and the ultimate users of the item are aware of the established reliability levels and can work to assure their attainment. This assumes the existence of 1) testing or verification procedures to determine the actual level of reliability and 2) management control procedures to handle any variance between the desired and actual levels of reliability attained. The management control procedures should be specified in a management plan. While reliability considerations can be very useful they are not a panacea as the following examples will demonstrate:

1) When using MTBF as a reliability criteria how is a component which does not fail but goes into degraded operation handled. It is not a black and white but

a grey area. If specifications were written to cover all grey areas they would be voluminous.

2) Determining reliability and cost estimates for marginal analysis is expensive and time consuming.

3) At present the performance of some systems is difficult to quantify and does not lend itself to quantitative values which can be utilized for reliability specifications; i.e., voice communications systems. The object of the system is to pass intelligible information. How is "intelligible" defined? MIL-STD-188C revised 24 Nov. 1969 gives the following performance objectives. "Tactical transmission system volume, loop losses, switch losses and inter-office trunks shall be engineered to provide the following listeners preference ratings in terms of listeners preferences:

   85% of the users will rate the circuit "Good".
   10% of the users will rate the circuit "Fair".
   5% of the users will rate the circuit "Poor or Worse"." [17, p. 70]

Although these are performance criteria, they do not satisfy the criteria of quantitative, reliability specifications.

B. MAINTAINABILITY

Maintainability definition: A time function, the probability, understated conditions, that a maintenance process will terminate successfully within a stated time measured from initiation of the process.

The maintenance need can be brought on by degraded operation, catastrophic failure or because of the lapse of a predicted reliability time period. The maintenance process can be preventative maintenance which considers time as a constant, either because regular periods of fixed duration are provided for the purpose or because the tasks are so routine that performance times exhibit negligible dispersion. On the other hand corrective maintenance typically involves unforseen contingencies such as catastrophic failure or systems deterioration while still performing above a "failed" level [18, p. 137].

Reliability is one side of the system "availability" coin. Though complex equipment can fail, reliability has attained a degree of sophistication that makes it possible to predict failure rates with a fair degree of accuracy. The other side of the coin, maintainability, presents a problem. Even though the need for maintainability has been recognized in some quarters it has not received wide attention and therefore has not reached the stage where it can be effectively quantified with any appreciable degree of acceptance. Since most things are fallible, maintainability, or the need for it, is a fact of life. When failure occurs repair is required and the faster the better. If either "ability" fails to do its job, or fails to support the other, availability suffers. [19, p. 1-5].

A useful description of availability is contained in NAVSHIPS 94324. The mathematical approached used is

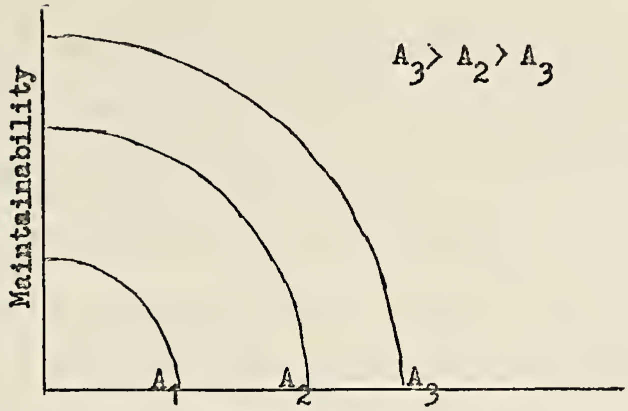
$A = R + M_O\ (1-R)$

where A is the availability, R is the equipment reliability and M_O is the operational maintainability of the equipment. [20, p. 3].

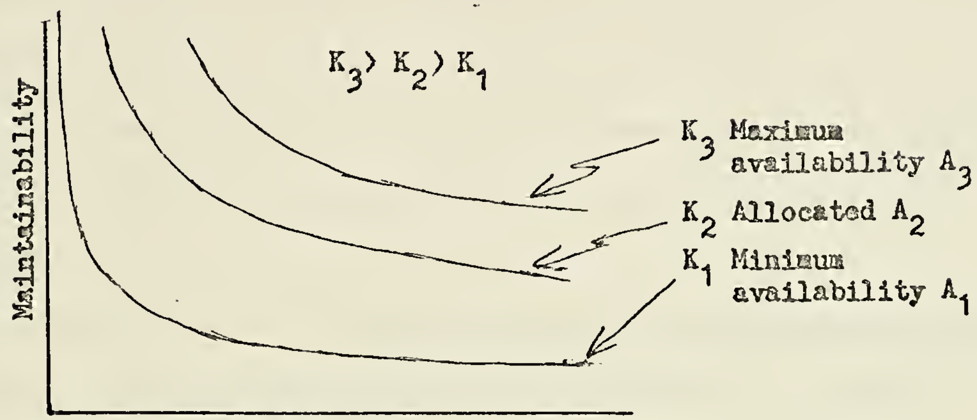
The initial Concept Formulation phase, when a future system is being considered and the alternatives are being examined, is when maintainability long range goals should first be considered. From the point in time when reliability becomes a consideration maintainability must also be present. In the Concept Formulation phase, maintainability functions such as, logistics, support systems, personnel and training must be present and kept visible throughout the system evolution.

Maintainability requires an integration of design and maintenance engineering effort to provide controls which assure that the system being designed is adequately, expeditiously, and economically supported. Maintainability is a design parameter which reflects support considerations, and is prerequisite to integrated logistics support. [8, p. 117].

Quantitative maintainability values must be determined by considering trade-off's with reliability and cost. Figure 2-3a represents trade-off alternatives between reliability and maintainability at a constant availability level. Figure 2 - 3b shows the effect upon reliability and maintainability of cost and Figure 2-3c depicts the trade-offs between availability, reliability, maintainability and cost. During this phase the system characteristics must be determined

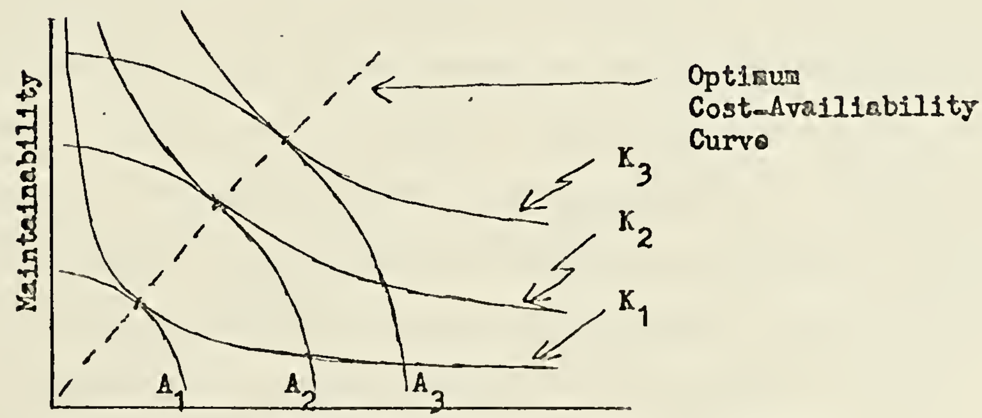


Reliability
Figure 2-3A
Equal Availability Curves



Reliability
Figure 2-3B

Equal Cost Curves



Reliability
Figure 2-3C
Optimum Cost-Availability Curve

Adapted from Eimstad (21, p. 337)

and used as guidance. The basic methods of construction (extent of modularity, accessibility, fastenings, plug-in and wire-in features, etc.), the location and circuit protection of test points, the level of the lowest replaceable unit (LRU's), the extent to which automatic fault detection (AFD) and built-in test equipment (BITE) will be provided, the type and extent of fault isolation and localization software (programs for AFD and technical manuals and data for maintenance men), and the nature and degree to which on-line performance monitoring and testing is to be provided, must all be specified during the Contract Definition phase. [21, p. 33].

Various models have been developed based upon mathematical distribution models to aid in quantifying maintainability [22, p. 501] [18, p. 137] [20, p. 3].

If we are to profit from the ground work performed during the previous phases, the Acquisition and Operational phases must be guided by two paramount considerations. First we must be prepared to perform the management function of control. Controlling is the management function of making sure that plans succeed. In other words, it is the measuring and correcting of activities to ensure that these activities are contributing to the achievement of planned goals. [23, p. 507]. During the Concept Formulation and Contract Definition phases standards for maintainability were established; during Acquisition and Operations maintainability performance must be measured and deviations from the standards corrected.

Measurement is the second paramount consideration. Since we are concerned with systems availability which we plan to enhance through systems maintainability, we must have a means to test the systems maintainability to be able to quantify the level of performance.

Test procedures which test the entire system and not components of it, are very hard to find, and are the subject of this paper.

III. MODES OF FAILURE

This chapter will attempt to analyze failure; its causes, types, occurrence and effects.

A. CLASSIFICATIONS OF FAILURE

Failures can be classified according to location or cause. A classification of defects according to the location of failure determines a weak point in a system and is the first step needed to strengthen it. The reason for the occurrence of the failure can be analyzed as follows:

Design defects: Defects attributable to design imperfections. Pushing the state of the art or failure to consider all possible stimuli and responses of a system lead to design defects.

Manufacturing defects: Failures of this class occur as a consequence of violation of the technological manufacturing procedure chosen for the system or unit. The quality of the individual units and components of a system have unavoidable random variations. These manufacturing variations, decrease the reliability of some of the items or units.

Improper use: For every system, restrictions are made on the conditions of its use. Rules are given for maintenance and operation of the system and its parts. Violations of these rules or restrictions may lead to premature failure.

Deterioration (aging): No matter how high the quality of the unit and/or the system as a whole, gradual wear or aging

is inevitable. During the course of use and storage, irreversible changes take place in metals, plastics and other basic materials. The cumulative effect of these changes deteriorates the strength, coordination and interaction of the parts. This deterioration may not be as readily apparent as an outright failure. The piece of equipment or system is still operating but at a sub-optimal level of performance. All components, subsystems and systems are subject to deterioration which in the final analysis may cause failure.

B. TYPES OF FAILURE

Instantaneous failure: Failures occur at the instant an operational parameter is exceeded. These failures are random. Typically the failure of the unit or system occurs independently of how long it has been used or what condition it is in. An example of this, is connecting a 110 volt appliance to a 440 volt power supply. The failure is instantaneous and usually readily apparent, no test may be necessary.

Degradation failure: This failure occurs as the result of the gradual change in operating parameters. Admissible limits for the operating parameters of a unit or system are established when it is designed. A performance parameter operating outside these limits is classified as a failure. [24, p. 5]. All units or systems are subject to wear or aging and therefore their condition is continually changing or transient; usually it is deteriorating. A minimum performance limit is established and the unit or system will approach this limit throughout its lifetime. This state is known as

"graceful degradation." A test procedure is needed to determine how much degradation has occurred.

Interaction failure: A situation in which several causes of failure act simultaneously. It is the most typical type of failure in practice. A vacuum tube may fail because it was subjected to a random "peak" load, after graceful degradation had lowered its upper level limit. The result is instantaneous failure. Interaction failure can be reduced by calibration which restores the upper limit to its proper level, if the amount of degradation is known.

C. OCCURRENCE OF FAILURE

The occurrence of failure is examined by analyzing the distribution of failures with respect to time, especially for components utilizing electronic technology. Figure 3-1 shows the classical failure rate for a finite population of newly manufactured components under a uniform operating stress. The failure rate curve is referred to as the bathtub curve. It is based on the presumption that failures will be fixed as fast as they occur, to keep the component operating. Virtually all components start their life with a very high initial failure rate, largely because of design and manufacturing deficiencies which economical quality control cannot find. This period is known as a debugging, or burn-in or infant mortality period. Following the burn-in period, the component enters its useful life period. Toward the end of the useful life, so many parts are deteriorating so fast that maintenance becomes uneconomical, the failure rate begins to

rise and the component enters its wear-out phase or end of life [25, p. 2].

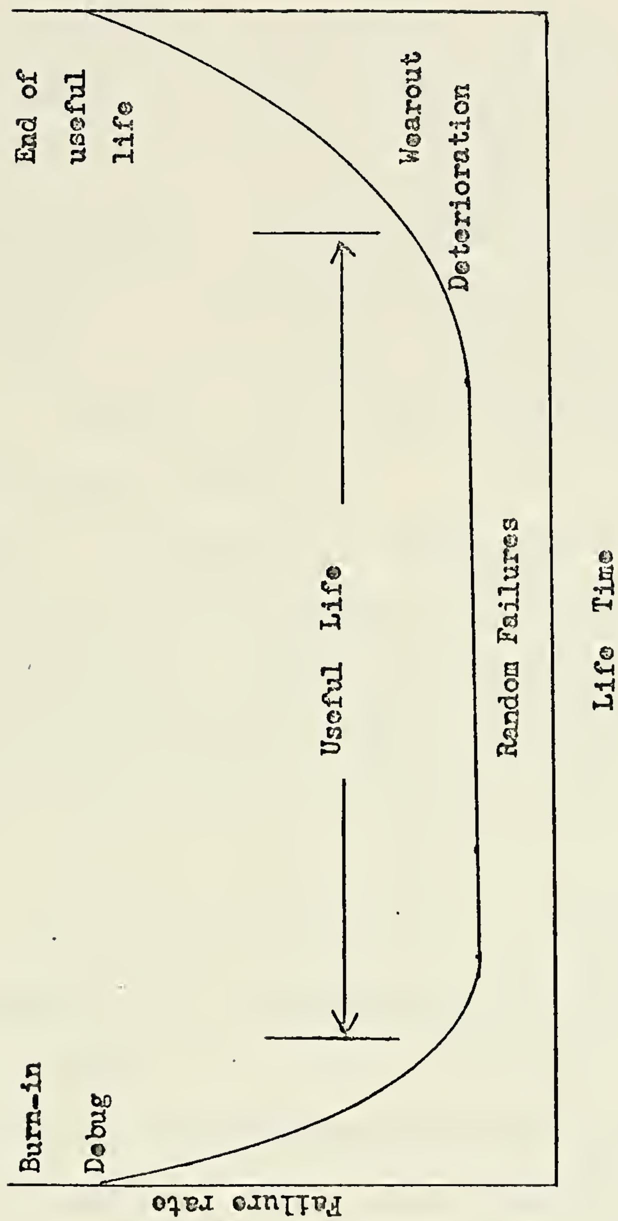
The classical failure rate has been challenged with respect to its validity from the user's point of view as applied to electrical components. Most contracts call for a manufacturer's burn-in period prior to acceptance. For the user the burn-in period is nearly non-existent. With integrated circuits, printed circuits, chips, transistors, etc., most electrical components are obsolete and are replaced before they enter the wear-out phase so it does not apply.

Examination of the useful life period calls for following a subtle line of reasoning and the solving of a contradiction, which this paper will not attempt. The first argument says that, given adequate preventative maintenance, experience has shown that the failure rate is fairly constant during this period. The second argument says that since the failure rate during the useful life period is determined by random failures preventative maintenance will have no effect upon the failure rate and therefore serves no purpose. Both arguments accept useful life failure and the existence of degradation which may impede a component's performance while not lowering it to a "failure" status.

F. EFFECTS OF FAILURE

The effects of failure can be as varied as the user, the component or the system which has failed. The effect could range from insignificance to catastrophy and loss of life.

In order to avoid the effects of failure, missions are curtailed or altered, duplicate systems (redundancy) are employed and several more expensive solutions are implemented.



"Bathtub Curve" of Life Failure Rate

Adapted from Winlund (25 - p.5)

Figure 3 - 1

IV. PRESENT TEST PROCEDURES

Before examining test procedures, equipment levels will be defined.

Component: A component, (subassembly, assembly, unit or group) is any collection of pieces which composes a subdivision of a set, piece of equipment or system. By itself it is capable of independent operation but it is not capable of performing a complete operational function. It is usually replaceable as a whole, but has parts which may be individually replaceable. (Examples: Electronic power supply, radio receiver, antenna group, oscillator).

Equipment (set): A component or components and necessary parts connected or associated together to perform an operational function. (Examples: Radio receiving set, sound measuring set, which includes such parts and components as cable, microphone and measuring instruments; radar homing set).

Subsystem: A subsystem is defined as a combination of equipments, components, etc., which perform an operational function within a system.

Subsystems from the major subdivisions of systems. Examples: (a radar station, fire control subsystem, a radio transmitting facility.

System (Electrical-Electronics): A combination of equipment and/or subassemblies, generally physically separated when in operation and other such components necessary to

perform an operational function or functions. Examples: (Antiaircraft defense system including tracking radar, computer and gun mount; GCA electronic system; communications system: A link including transmitter, medium of transmission and receiver). [26, p. 4].

In order to determine the level of operation of a test procedure we must specify the level of operation of the item being tested. The composition and the characteristics which must be measured at each level must be specified. Once the characteristics being tested have been defined, the level of operation of the item and the test system can be defined. Table (4-1) attempts to categorize and arrange the equipment levels and the characteristics measured.

A capsule summary of the prominent test procedures used in Naval Communications will follow. It must be understood that variations in tests occur from ship to ship and fleet to fleet, however an attempt will be made to provide a basic, objective guideline and discussion of each procedure.

The Quality Monitoring System (QMS) is a subsystem level performance monitoring procedure. It is composed of hard wired, monitoring equipment which is interfaced into the communications system at key points. It can be used on-line or off-line to measure degradation of selected characteristics. It requires extensive training and is expensive to install, however, quantum improvements in communications system performance can be obtained when QMS is properly used. QMS is capable of performing qualitative, voice, systems level testing. [27]

Level	Mechanical makeup	Electronic composition	Functional makeup	Characteristics measured
System	Geographically dispersed	Complex equipment groups	Radar Navigation Sonar Communication Data-Processing centers	Availability, Flow of information
Subsystem	Located in one area or vehicle	Racks Cabinets	Transmitters Displays Arrays Control units	Power output Signals strength Noise Light output % modulation
Equipment	Complete drawers Parts of racks	Power supplies Functional units or sections	Complete: Freq. sources Multipliers Receiver Modulators Control units Servo units	Sensitivity Selectivity Stability Distortion %modulation
Component	Assemblies	Functional units	Amplifiers Modulators Switches Generators Control units	Sections of: Sensitivity Selectivity Stability Distortion

EQUIPMENT MEASUREMENT LEVELS from Thomas & Clark [26, p. 3]

Table (4 - 1)

Pomsee is a subsystem level calibration test. It can be performed aboard ship but its best application is ashore at a depot level maintenance facility. Equipment must be removed and dismantled and is tested on a test bench. It is costly, time consuming and requires a high level of training to be properly performed. It is best applied to pieces of equipment which are known to have failed and not as preventative maintenance or in order to locate a failure.

Built-in test equipment (BITE) is a confusing title to apply to a test procedure. QMS could be considered built-in test equipment, however the term usually applies to component or equipment level "self-test" procedures. BITE is capable of being applied at the subsystem or system level, however, it is not done in practice because of cost. It usually provides a GO/NO-GO indication, a continuity check of cables and connections and requires an insignificant amount of time to perform. No special training is required to use the test. Its primary draw-backs are cost, one test circuit or piece of test equipment is required for each item being tested, and the sparcity of trouble shooting information available, it usually won't say what component failed or why. [28, p. 4-1]

The Standard Measurement Technique (SMT) is a quantitative, system level, test which measures the flow of information being processed by the system. It can be hard wired or patched in. It is an inplace, off-line test which is capable of quantifying the system ability to process degraded inputs.

It requires very little training, is moderately expensive and can be performed in minutes. SMT is being developed by the Naval Electronic System Command and a complete description of the system is provided in the following chapter.

The Planned Maintenance System (PMS) is a subsystem level, off-line GO/NO-GO test. It can be used on a daily basis and requires B-school training to perform. Portions of it can be performed with less training and portions will require higher training, more time and a test bench. PMS can be hard wired into the system but it is usually patched in, using portable equipment. The use of portable test equipment presents a problem because the equipment is often "banged" out of calibration rendering it unreliable. PMS is used to locate a failed piece of equipment. The 3M cards are used with PMS. The 3M test procedure is a subsystem level maintenance procedure. Basically it is a check list, set of instructions listed on a card which describes a test, lists the equipment necessary and gives step by step instructions on how to perform the test. It can be performed off-line, or on a test bench. Fleet studies have indicated that component and equipment level 3M/PMS testing is performed in the fleet but that subsystem level testing is not performed. [29]

Table 4-2 presents the various test procedures and attempts to show the significant criteria which can be used to compare them with each other.

The definition of each criteria used in Table 4-2 is as follows:

Component, equipment, subsystem and system - as presented at the beginning of this section or Table 4-1.

Detect failure - can the test procedure detect a failure at the highest level of performance given?

Detect degradation - can the test procedure detect degradation at the highest level of performance given?

Quantitative - does the test procedure provide a quantitative read-out (as opposed to a GO/NO-GO type output) at the highest level of performance given?

Measure flow of information - does the test procedure have the ability to measure the flow of information in the system?

Performed daily - is the time needed to perform the test such that it can be performed daily?

Remove and replace - does the item to be tested have to be removed in order to be tested?

High training - is a high level of training (B-school) necessary in order to be able to perform the test?

It must be pointed out that table (4-2) does not consider the cost of each test procedure. Cost analysis must be considered before any test can be considered optimal.

The items which should be given major consideration are System, measure flow of information, performed daily and high level of training. These are the items which the user of the test equipment is interested in and upon which his judgment will decide <u>if he will use</u> the test procedure.

	Component	Equipment	Subsystem	System*	Detect failure	Detect degradation	Quantitative	Measure flow of info.*	Performed daily*	Remove and replace	High training*	COMMENTS
QMS	Y	Y	Y	N	Y	Y	Y	N	Y	N	Y	Subjective test at systems level, can be used for voice system.
PMS/3M	Y	Y	Y	N	Y	N	N	N	Y	N	Y	Subjective test at systems level, not performed in fleet at subsystem level, many items must be removed and replaced.
SMT	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	
POMSEE	Y	Y	Y	N	Y	Y	Y	N	N	Y	Y	Suitable for depot level not shipboard. Not performed in fleet.
BITE	Y	Y	Y	N	Y	N	N	N	Y	N	N	Expensive; one piece of test equipment for each piece of equipment.

Detect failure, degradation and quantitative output at highest level of performance.
* Item of major importance

Y Yes

N No

TEST PROCEDURE COMPARISON

(Table 4 - 2)

V. STANDARD MEASUREMENT TECHNIQUE

A. GENERAL CONCEPT OF STANDARD MEASUREMENT TECHNIQUE

Studies and communication exercises performed over the years have pointed out again and again, the fact that an adequate method of determining communications SYSTEM performance does not exist. This chapter will attempt to offer a solution to this problem.

Performance evaluation has been confined to a lengthy and complicated (POMSEE etc.) evaluation of individual equipments and proceeded on an assumption that proper operation of system components ensured satisfactory operation of the total system. This viewpoint ignores the fact that systems are often synergistic and presupposes component performance levels are linear and arithmetically additive.

The emphasis on individual equipment performance often resulted in catastrophic equipment failure as the sole criteria for maintenance action while quantum system performance degradations went largely unnoticed. [30, p. 3 - 1 to 3 - 17].

A major weakness of the conventional methods for testing and maintenance of communications systems is the inability to test for varying levels of degradation in the system. Attempts to establish a communications circuit using ostensibly operational equipments often resulted in failure. Diagnosis of circuit malfunctions did not isolate faults to the ship or shore termination, the atmosphere, or the identification of faulty system components at the specified site.

The genesis of some of these problems can be found early in the equipment life cycle. During acquisition equipments are tested by various parameters, levels, procedures and conditions. The ambiguities in equipment performance levels often limit the amount of predictive analysis a communications systems engineer can perform prior to system implementation resulting in performance requirements written post facto.

Subsequent system testing (OPCAP, INSURV, etc.) frequently utilize a shore termination as an operational standard. Since the standard has not been tied to a reference point utilizing strict methodology the predictive performance aspects of the system operating with different terminations often suffer.

A need for formalized testing methodology, from equipment level to systems level, is evident. An additional necessity is the establishment of minimum system performance levels. All too often system levels are established at or near design levels (as new or refurbished equipments) without an adequate determination of allowable performance deterioration due to aging. As a consequence, equipment replacement or overhaul can become a qualitative judgment without adequate consideration of an equipments' effect on its suit or ancillary equipment.

The Standard Measurement Techniques (SMT) will fill this long-standing need. The SMT will provide ships and shore stations with techniques and procedures for testing and measuring overall communications effectiveness on a system, subsystem, equipment, and circuit level without an emphasis

on automation, the need for general purpose digital computers, or highly trained operators and technicians. With the use of magnetic tape inputs and the traditional approach to communication testing, a valuable new technique is developed.

The evaluation of system operation can be determined rapidly by the following technique: Prerecorded teletype signals with various levels of degradation, such as distortion and atmospheric disturbance will be available on magnetic tapes. The tapes allow a communication system to be checked under varying conditions that are experienced in actual ship and shore operations.

The National Bureau of Standards and the Pacific Missile Range will pretest, verify and supply the magnetic tapes.

The various test signals and the utilization of existing displays will permit interpretation on, a GO/NO-GO basis, the ability of the system to meet functional specifications.

To provide for universal testing it is necessary to accomplish the following long range goals:

a. Define and describe present systems.

   An Engineering Data Register (EDR) has been promulgated to define the pertinent characteristics and specified parameter values for each Naval Communications System.

b. Establish numerical systems performance levels.

   Reference Level Measurement Guides (RLMG) will establish acceptance levels criteria for systems and equipment. They will specify the following

for a particular communications system:

- which parameter is to be tested.
- the value or level for measured parameter.
- which measurement method in the SMT should be used.

c. Develop techniques for measuring system performance levels. The SMT defines the applicable technique for measuring each characteristic in conjunction with testing the overall system performance.

In a letter to the Chief of Naval Operation (CNO), dated 21 Sept. 1972, the Commander, Naval Electronic Systems Command stated the following:

"The purpose of SMT is two-fold. First, it measures communications system's performance to determine system's operational capability. Secondly, it has the capability to locate or identify equipments that are not performing properly. The tests are conducted on record, and voice communications systems under simulated, controlled, repeatable conditions that exercise all parameters of a system. The test can be performed at sea or in port without need for assistance from other ships or shore stations." [31].

In order to contrast the SMT approach with present testing methods, the following distinctions are made:

Philosophy of present testing methods: The basic principle of the current testing methods is that the better a system is, the less it will distort the most perfect signal. Tests are conducted for distortion of a single characteristic.

Philosophy of SMT testing methods: The basic principle of testing methods with SMT is that the better a system is, the greater degradation of input it will withstand and continue to operate. Tests are conducted for system response to maximum distortions of multiple characteristics. [32]

Six types of system degradation are examined with SMT:

. Teletype Distortion: Teletype systems are tested by introducing five lines of test in successively increased amounts of distortion from a tape, each line containing a different type of distortion. The terminal teletype of the subsystem is then checked to determine at what point the system fails to produce an error-free copy.

. Atmospheric Distortion: Teletype systems are tested by introducing ninety lines of test with Multipath, Noise and Fade from a tape to check the system's diversity capability and the receiver subsystem's response to signal amplitude fluctuation and sensitivity (S/N). The terminal teletype of the system/subsystem under test is examined to determine the system's capability to produce an acceptable copy.

. Transmitter Spectral Purity: A system's transmitter is tested by examining its output with a spectrum analyzer for percentage of modulation, harmonic distortion, intermodulation distortion, and suppressed carrier level.

. Articulation Index (AI): Voice systems are tested by inputing various audio frequencies and a precise amount of noise from a tape. The receiver output is then measured with a noise measuring set to determine the intelligibility capability of the system.

. Multicoupler/Coupler Swept Frequency Response: A system's multicoupler is tested by introducing various frequencies from a tracking generator into the system's multicoupler and examining its output with a spectrum analyzer to determine loss or gain, bandpass, ripple factor and skirt characteristics.

. Antenna Swept Frequency Response: A system's antenna is tested by introducing a continuous spectrum sweep from a tracking generator at the antenna through a directional bridge. The output is then examined on a spectrum analyzer to determine the standing wave ratio and resonant frequency of the antenna. The antenna signature presented on the spectrum analyzer is photographed and maintained as a maintenance standard. [32]

B. SPECIFIC OBJECTIVES OF SMT

We are primarily concerned with the questions of whether communication equipment is operational, and at what degradation level it becomes inoperable. Therefore, the scope of the Standard Measurement Techniques program involves four levels of testing, each progressively more detailed. Tests are:

1. SYSTEM TEST
2. SUB-SYSTEM TEST
3. EQUIPMENT TEST
4. CIRCUIT TEST

The tests are designed with the following objectives:

a. Test for system response to maximum distortion of a multiple of characteristics with a minimum of tests.

Reliability; tests are to duplicate real world communications environments and will measure system performance under worst-case conditions. Systems orientation; emphasis on providing realistic simulated inputs to systems and observation of resultant outputs. Define numerical system parameters for inclusion in a Reference Level Measurement Guide (RLMG) and establish acceptance/rejection criteria. Performance level indices; numerical analysis of system performance vice a reliance on GO/NO GO judgments to provide a measurement of system quality.

b. Utilize the existing system equipments to interpret results. Economy; an avoidance of automation, computers, and highly trained personnel. Design goal is to provide total SMT capability for less than $5000.00 per site.

c. Minimize the number, sophistication and time of tests and technicians. Speed; complete systems tests in less than 15 minutes per test. Simplicity; test procedures that are straightforward and easily understood by operational personnel at the fleet level.

d. Maximize confidence in the validity of system acceptance.

e. Establish capability to rapidly and confidently ascertain particular system, subsystem or equipment characteristics which do meet specified parameter values or tolerances.

f. Commonality for all communications systems. Independence; performance of SMT measurements that are RF silent, self contained, and can be accomplished without support of off-site activities. Devise and establish Standard Measurement Techniques (SMT) for testing and measuring system performance levels of communications systems employed at communications stations afloat and ashore. Develop and prepare Detailed Test Plans (DTP) tailored to a specific platform/site and establish procedures for reporting results of testing performed. [33, p. 2]

C. TEST PROCEDURES

The RLMG describes system tests necessary to ascertain that equipment characteristics meet the specifications listed in the EDR.

Test Notes

a. Each test procedure is furnished with a block diagram for use during test set-up. The test equipment is shaded for clarity.

b. A one hour warm-up period is recommended to stabilize the system and test equipment.

c. Safety Procedures: NAVSHIPS 250-660-42, Electric Shock Its Causes and Prevention, should be made available to personnel engaged in testing.

d. Equipment that is essentially passive, e.g., receive and transmit switchboards and interconnecting lines,

is assumed to have been tested prior to start of system tests. [34, p. 1-2].

Functional System Tests (Figure 5-1) can be used for systems orientation.

System Test Part 1. TTY end equipment.

System Test Part 2. System Test with TTY Distortion

System Test Part 3. Receive System Test with Atmospheric Distortion

System Test Part 4. Antenna (Transmit and Receive)

System Test Part 1: TTY end equipment

System Test No. 1 is a teletype "end equipment" functional check of reperforator and page printer only on a closed loop basis via the DC patch panels. Teletype distortion tape: Five lines of test, each line containing a different type of distortion, line 1, MARK BIAS, line 2 SPACE BIAS, line 3 SWITCHED BIAS, line 4 SPACE END, and line 5 MARK END will be transmitted in successively increased amounts of distortion, 5% increments, through 45% distortion. The end equipment or teletype of the system/sub-system under test will be checked to determine at what point the teletype machine fails to produce an error-free copy. [35, p. ii]

Procedure details for system test part 1:

a. Patch the tape recorder to the DC patch panel. Patch DC patch panel to page printer.

b. Send type test message; TEST THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG'S BACK 123456789Ø testing.

c. Verify printed test message at page printer.

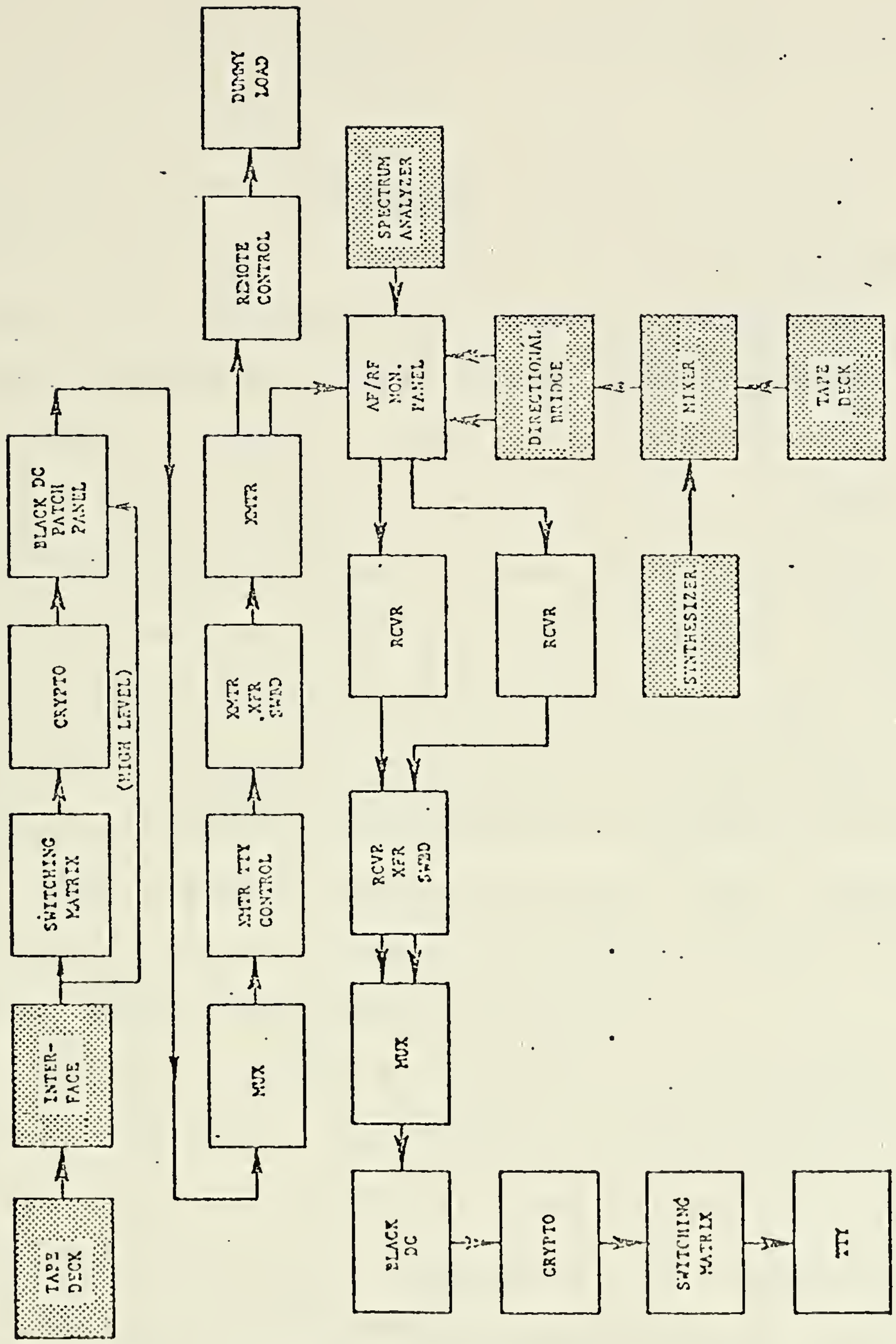


Figure 5-1 Functional System Block Diagram
Multichannel, Duplex, AFTS, RATT
"P" System

d. Repeat test message for each channel of "P" system.

e. Objective of the test is to ensure proper operation of perforators and page printers. Figure 5-2 is a block diagram of the test. Table 5 - 1 is an example of the printed page messages.

System Test Part 2: System test with TTY distortion

System Test Part 2 is a quantitative semi-full system loop test. The following technique will demonstrate the overall system performance and its capability to perform with known distorted signals. Input to the system is provided by a magnetic tape recorder. The tape recorder will have four (4) instrumentation channels. Three instrumentations channels will have prerecorded teletype signals which are degraded at successive intervals with various levels and types of distortion such as space bias distortion and spacing end distortion. The fourth instrumentation challel will be used for the tape recorder speed servo control loop. The test tape used in test Part 1 is used for this test. [33, p. 7].

Procedure details for system test Part 2.

a. The tape recorder is patched via an interface unit, to the DC patch panel. The transmit antenna lead is removed from the antenna and patched to a dummy load. The transmitter is patched to the monitor equipments. The receive antenna lead is removed from the antenna and patched to the monitor equipment. This series of connections makes a loop permitting a test signal to be introduced by the tape via the DC patch panel. The test signal is sent through the transmit system

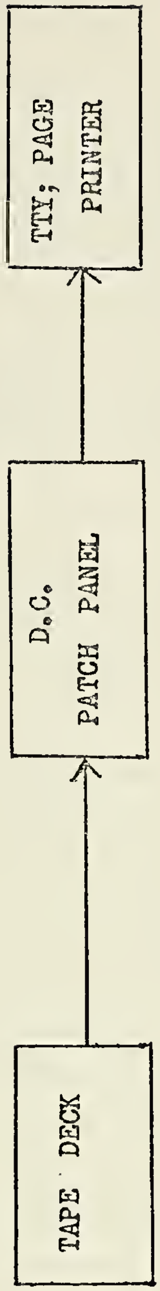


Figure 5 - 2 TTY Test

System Test Part 1 "P" System

STANDARD MEASUREMENT SYSTEM TEST TAPE

DISTORTION HEADING

LINE ONE	MARK BIAS DISTORTION
LINE TWO	SPACE BIAS DISTORTION
LINE THREE	SWITCHED BIAS DISTORTION
LINE FOUR	SPACE END DISTORTION
LINE FIVE	MARK END DISTORTION

THE FOLLOWING FIVE LINES OF TYPE CONTAIN NO DISTORTION

THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING

THE FOLLOWING FIVE LINES OF TYPE CONTAIN THIRTY PERCENT DISTORTION

THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING

THE FOLLOWING FIVE LINES OF TYPE CONTAIN TEN PERCENT DISTORTION

THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING

THE FOLLOWING FIVE LINES OF TYPE CONTAIN THIRTYFIVE PERCENT DISTORTION

THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
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THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING

THE FOLLOWING FIVE LINES OF TYPE CONTAIN TWENTY PERCENT DISTORTION

THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING

THE FOLLOWING FIVE LINES OF TYPE CONTAIN FORTY PERCENT DISTORTION

THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
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THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING

THE FOLLOWING FIVE LINES OF TYPE CONTAIN TWENTYFIVE PERCENT DISTORTION

THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
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THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING

THE FOLLOWING FIVE LINES OF TYPE CONTAIN FORTYFIVE PERCENT DISTORTION

THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING
THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING

END OF TEST

STANDARD MEASUREMENT SYSTEM TEST TAPE

Table 5 - 1

to the monitor equipment, to the receive system to the page printer.

b. Send tape test message TEST THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG'S BACK 123456789Ø TESTING.

c. Verify printed test message at the page printer. When a NO-GO condition appears maintenance work can be accomplished by use of the Sub-System test 1, after all systems tests are complete.

d. Repeat message for each channel of "P" system or by using an interface panel test all channels at one time.

e. The objective of this test is to ensure proper operation, compatibility and performance of the system, excluding the two antenna systems, the effects of the propagation medium and the transmit TTY equipment. A block diagram, Fig. 5-3, is supplied for guidance, and table 5-2 lists the equipment necessary to perform the test.

System Test Part 3: Receive System test with atmospheric distortion.

System Test Part 3 is a quantitative, receiving system test. The following technique will directly imply the level of performance to which the system will operate. Input to the system is provided by the magnetic tape recorder as used in Test No. 1. Three instrumentation channels will have prerecorded multichannel RATT messages which are degraded at successive intervals with various levels and types of atmospheric conditions such as time spread distortion and noise. The fourth instrumentation channel will be for the tape

LIST OF TEST EQUIPMENT FOR SYSTEM TEST PART 2
[34, p. 2 - 8]

Description

1. Magnetic Tape Deck
2. Interface Unit
3. Spectrum Analyzer
4. Frequency Counter/Generator
5. Attenuator 120 db
6. Attenuator 12 db
7. Micro Voltmeter
8. Dummy Load
9. Power Dividers (2)
10. Line Fuse for Spectrum Analyzer
11. Test Tapes
12. Patch Cords

Table (5 - 2)

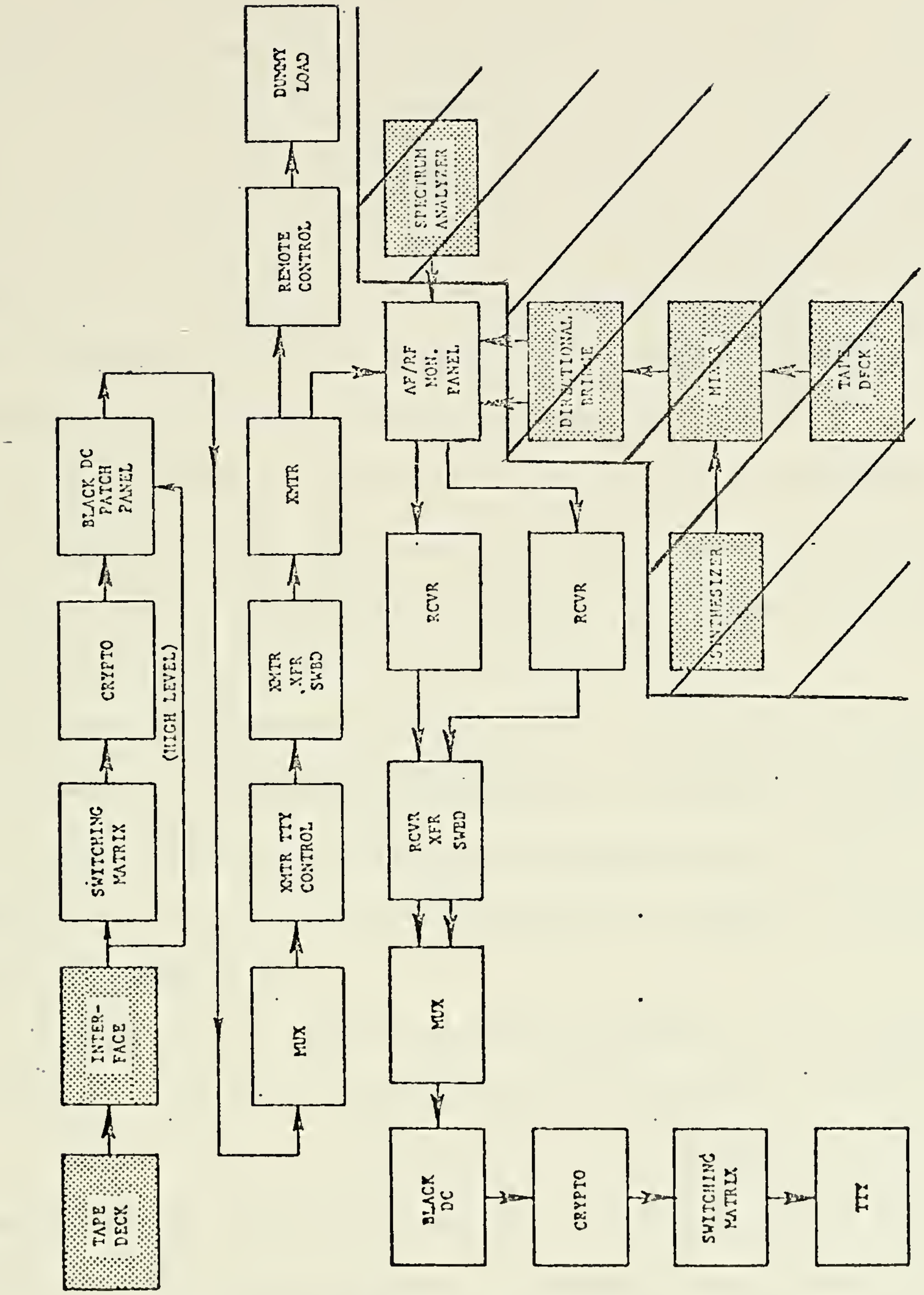


Figure 5-3 Semi-Full Loop Test

System Test Part 2-"P" System

recorder speed servo control loop. Atmospheric Distortion tape: Ninety lines of test, including thirty lines of MULTI-PATH distortion to determine the system diversity capability. Thirty lines of FADE to exercise the receive systems capability to respond to signal amplitude fluctuations (AGC). Thirty lines of NOISE, to test the receive systems sensitivity (S/N). In all cases, the end equipment, teletype, of the system/sub-system under test will be checked to determine the systems capability to produce an acceptable copy. (1 error in ten lines acceptable, for the system under test.) [33, p. 11]

Procedure details for system test part 3:

a. A synthesizer is utilized to supply an RF input to a mixer in conjunction with the input from the tape recorder. The test signal is processed through the receive system (input is below the antenna) to the page printer.

b. Send recorded RF signals, with atmospheric distortion.

c. Verify printed test message at the page printer. When a NO-GO condition appears maintenance work can be accomplished by use of the Sub-System 2, after all systems tests are completed.

d. Repeat test signal for each channel of "P" system or by using an interface panel test all channels at the same time.

e. The objective of this test is to demonstrate the operability and performance of the receiving system when exposed to the varying effects introduced by a test signal with known quantities of atmospheric distortion. A block diagram, fig. 5-4, is supplied for guidance and table 5-3 is a list of equipment needed to perform the test.

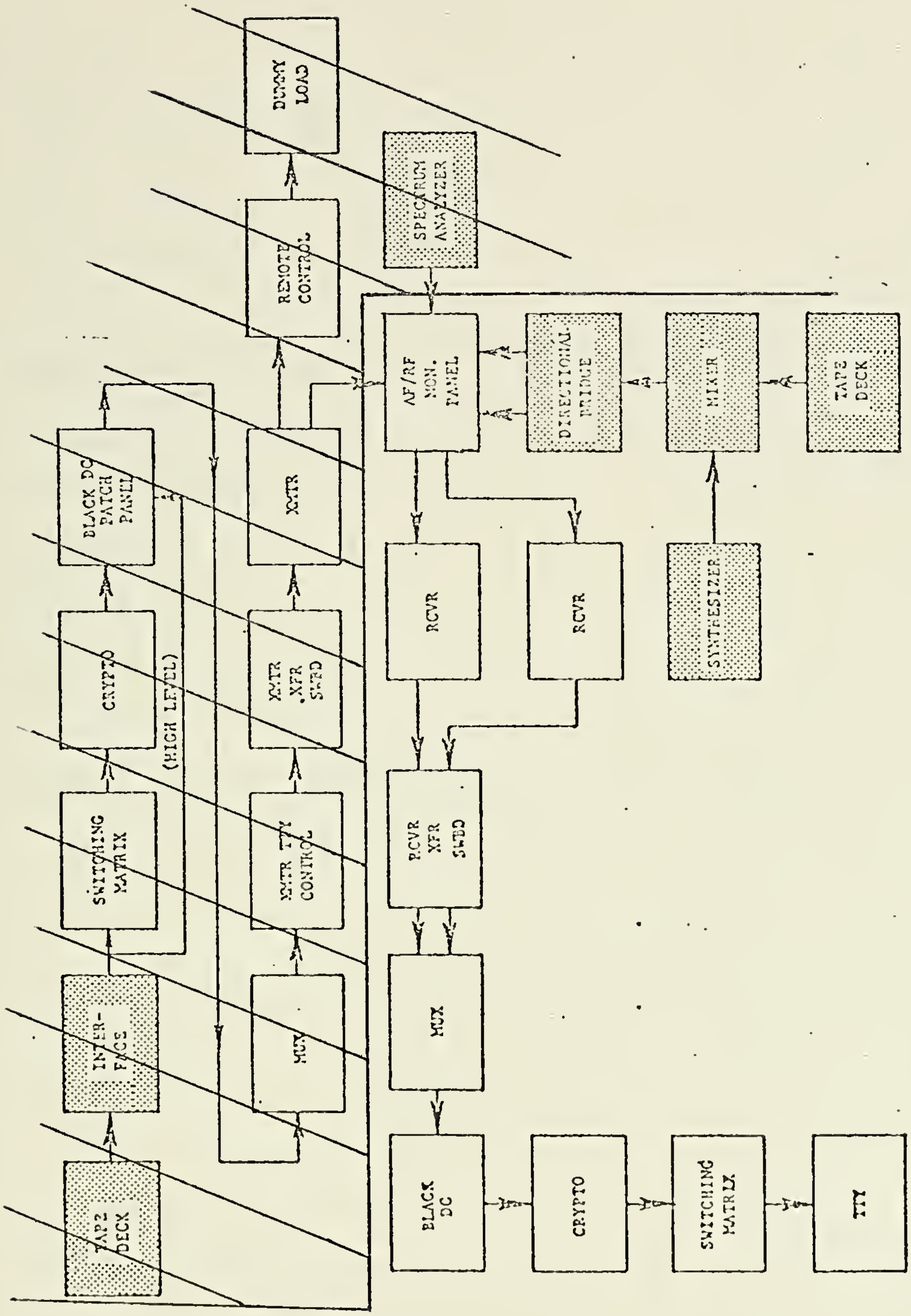


Figure 5-4 Receiving System

System Test Part 3 "P" System

LIST OF TEST EQUIPMENT FOR SYSTEMS TEST PART 3
[34, p. 2 - 15]

Description
1. Magnetic Tape Deck
2. Test Tapes
3. Synthesizer
4. Mixer
5. Attenuator 120 db
6. Attenuator 12 db
7. Micro Voltmeter
8. Power Divider
9. Line Fuse
10. Patch cards

Table (5 - 3)

Systems test Part 4: Transmit and Receive Antennas

System Test Part 4 is a transmit and receive antenna test. Input to the system is provided by the magnetic tape recorder. An instrumentation channel will have a prerecorded two-tone signal. This two-tone signal is supplied to the transmitter with a full power setting utilized for the transmit antenna. The transmit and receive antenna signals are evaluated at the Current Monitoring Panel (CMP). The receive antenna signal is provided by the transmit loop of the "P" system at a minimum level to prevent multicoupler overloading. [33, p. 15]

Procedure details for system test Part 4.

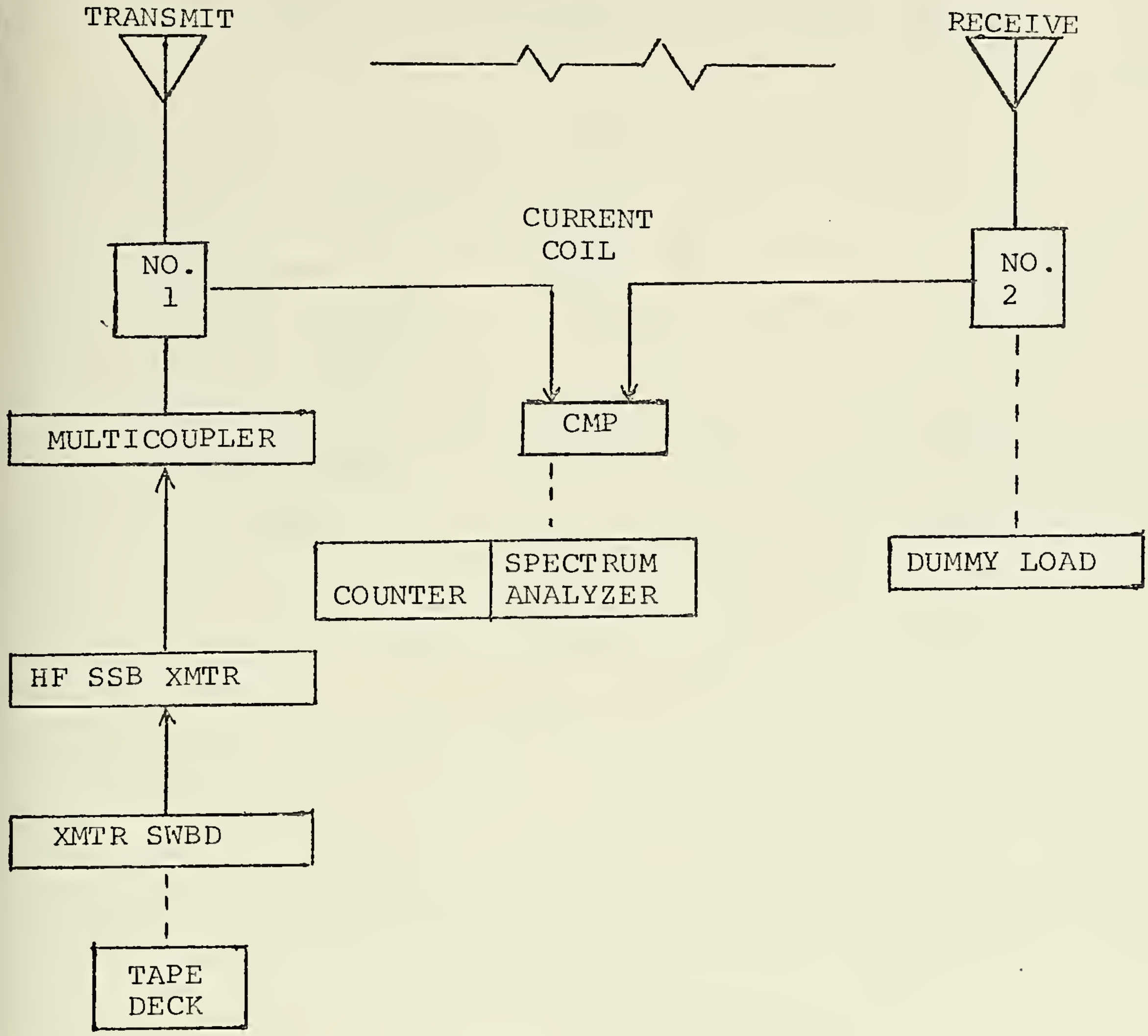
a. Patch tape recorder to the transmitter Switchboard. Attach a current coil to transmitter antenna lead and to the receive antenna lead. Connect both current coils to a current monitor panel. Patch a spectrum analyzer to the current monitor panel.

b. Record spectrum analyzer display and determine the standing wave ratio and resonant frequency of the antenna.

c. Send taped two-toned signal.

d. Repeat test for each antenna.

e. The objective of this test is to determine the efficient and inefficient frequencies (or frequency ranges) for each antenna. Reference Fig. (5-5) for a block diagram and table (5-4) for a list of equipment necessary to perform the test.



C. M. P.: CURRENT MONITORING PANEL

ANTENNA TEST
SYSTEM TEST PART 4 "P" SYSTEM

Figure 5 - 5

LIST OF TEST EQUIPMENT FOR SYSTEMS TEST 4
[34, p. 2 - 21]

Description

1. Magnetic tape deck
2. Test tapes
3. Spectrum Analyzer
4. Antenna current monitoring panel
5. Current coils
6. Patch cords

Table (5 - 4)

Sub-System Tests (Second level of the SMT)

The Sub-System Tests are designed to isolate a particular part of the communication system when a NO-GO condition appears during System Tests No. 2 or No. 3. There are two tests, two parts to each test. By a process of elimination, each test will pinpoint the NO-GO equipment or equipments for that particular test.

The other components in the circuits are essentially passive, i.e., receiver and transmit switchboards and interconnecting lines. Existing standard tests can be utilized for these items. The foregoing technique isolates the transmit and/or receive section of the overall system to enable the test personnel to pinpoint the exact NO-GO equipment. [33, p. 18]

Procedures for Sub-System Test No. 1

a. Set up test and monitor equipment as in Systems test Part 2 except that the tape recorder is patched to the transmitter switchboard instead of the D. C. patch panel. The tape recorder sends the test signals through the transmit section of the "P" system. After the transmitter is tested and verified the test tape input reverts back to the multichannel keys and the test is run again. Transmitter Spectral Purity: The transmitter under test will be tone modulated, 8 or 16 tones, as required and the output will be examined on a spectrum analyzer to determine

the spectral purity, (% of modulation, harmonic distortion, intermodulation distortion, and suppressed carrier level) that applies to the transmitter under test.

b. A black diagram, Fig. (5-6) is provided and table (5-5) is a list of equipment necessary to perform the test.

Procedures for Sub-System test 2:

a. Patch the tape recorder to the receiver switchboard and test the multichannel convertor. After the convertor is tested test the receiver as in System Test Part 3.

b. A block diagram, Fig. (5-7) is provided and table (5-6) is a list of equipment necessary to perform the test.

Voice Communications System Test

The Voice ystem Test is a test procedure whereby a systems ability to transfer intelligible information is measured by reference to an articulation Index (AI). "AI has been shown to be a function of the link description (type and frequency), and the strength of the derived and interfering signal, SRF and I, respectively; hence, for any given communications systems of such configuration that link and interferer descriptions and frequencies are known. AI can be established as a function of SRF and I." [36, p. 1]. Values of AI have been determined in terms of audio S/N values permitting voice system's intelligibility to be

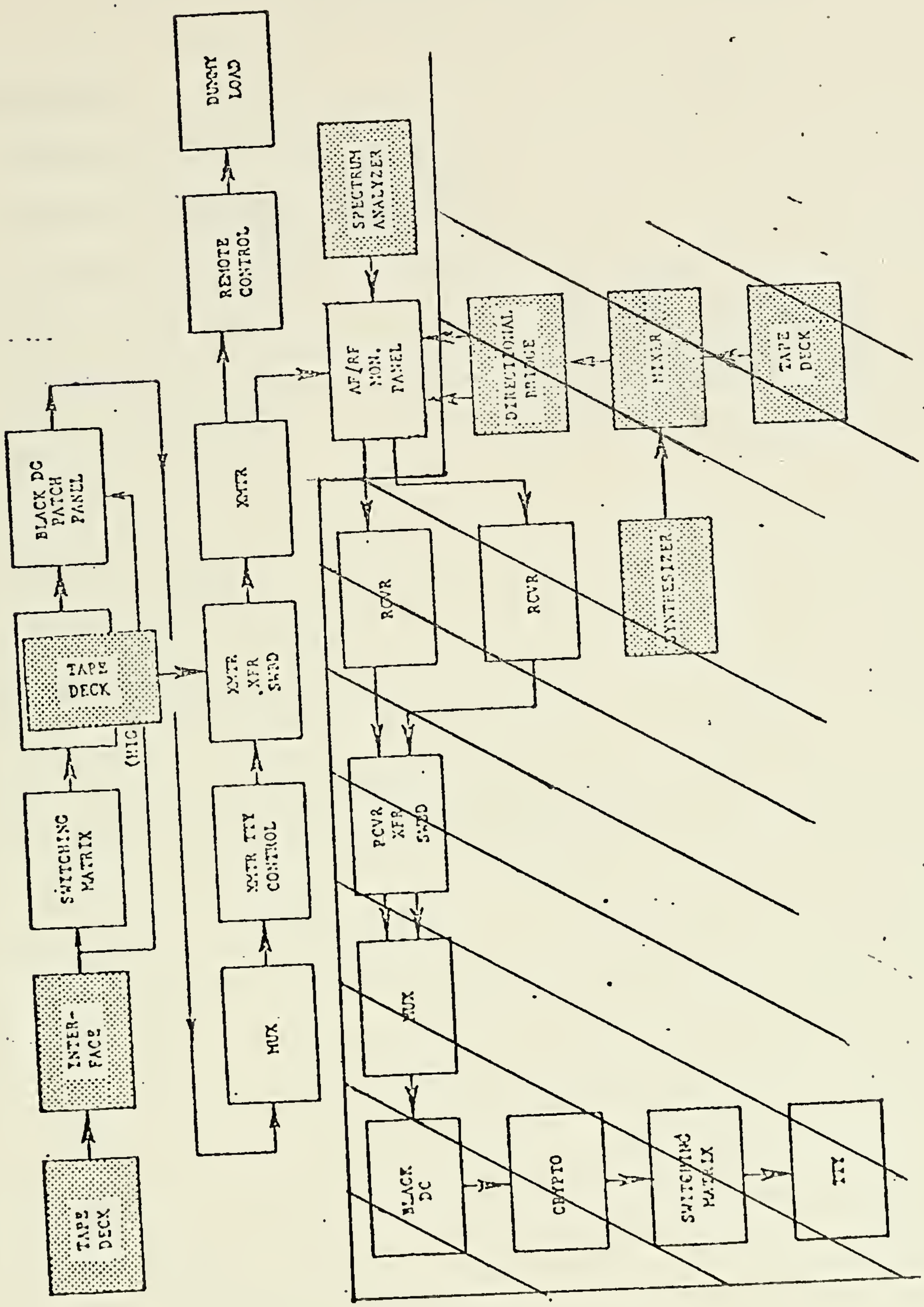


Figure 5-6 Transmitter Test

Sub-System Test 1 "P" System

LIST OF TEST EQUIPMENT FOR SUB-SYSTEM TEST 1
[31, p. 3 - 4]

<u>Description</u>

1. Magnetic Tape Deck
2. Frequency Counter/Generator
3. Spectrum Analyzer
4. Attenuator 120 db
5. Attenuator 12 db
6. Micro voltmeter
7. Dummy Load
8. Power Divider
9. Test Tapes
10. Patch Cords

Table (5-5)

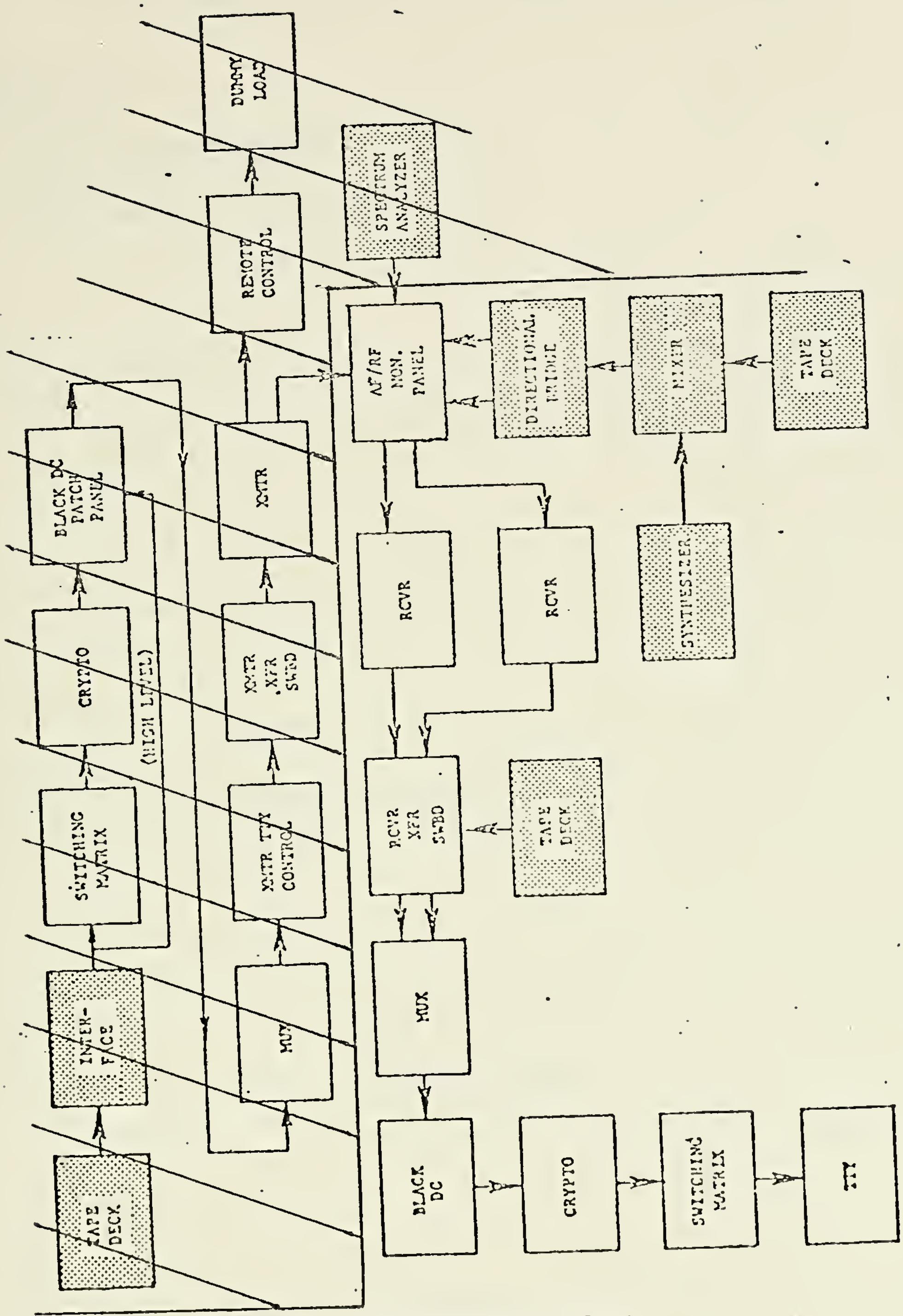


Figure 5-7 Multichannel Test

Sub-System Test 2 "P" System

LIST OF TEST EQUIPMENT FOR SUB-SYSTEM TEST 2
[31, p. 3 - 9]

Description
1. Magnetic Tape Deck
2. Test Tapes

Table (5 - 6)

measured in terms of a S/N ratio. [37]. Articulation Index (AI): A tape containing various audio frequencies and a precise amount of noise will be introduced into the system and the receiver output will be measured with a noise measuring set to determine the intelligibility capability of the system. This test is only used in voice systems. [31, p. iii].

Procedure details for voice system test:

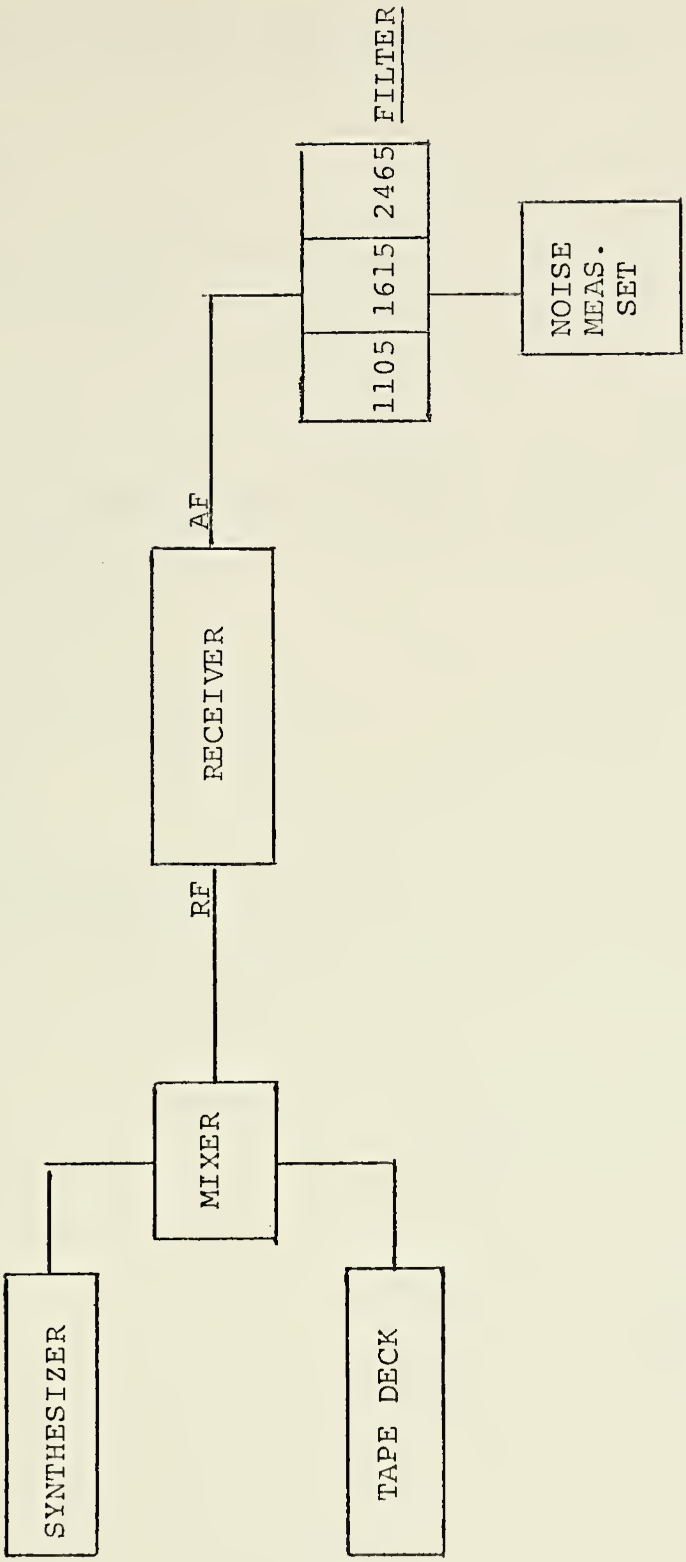
a. A taped signal containing audio frequencies and noise is processed through the receiver and the output signal is measured by a noise measuring set. The noise measuring set looks at the noise passed by 3 filters located in the voice band width. The difference between the input and output noise levels, expressed as S/N is equated to AI which is equated to intelligibility.

b. This test procedure is used to determine the performance of a receiver configured for voice communications only.

c. Figure 5-8 provides a block diagram of the test and table 5-7 provides a list of equipment necessary to perform the test.

D. APPLICATIONS AND RESULTS

Demonstrations have been conducted on board fleet units and at shore activities to validate design decisions made during SMT development, examine the universality of the



VOICE SYSTEM INTELLIGIBILITY TEST

Figure 5 - 8

VOICE COMMUNICATIONS TEST EQUIPMENT. [37]

Description
Random Noise Generator
True RMS Voltmeter
Amplifier
Wave Analyzer
Voice Interference Analysis System
Digital Voltmeter
Tape Recorder
Noise Measuring Set
Synthesizer
Attenuator
Attenuator/Rotary

Table 5 - 7

procedures, and to introduce communications system users to the capabilities of SMT. Demonstrations have been conducted at or on board USS England, USS Preble, USS Intrepid, NAVCOMMSTA SFran, Naval Postgraduate School, Monterey; USS Constellation and other Commands.

SMT performance has demonstrated that the original Long Range Goals can be satisfied. A number of present systems have been defined and described in the EDR. Numerical systems performance levels have been established in the RLMG and SMT has shown the techniques for measuring the systems performance levels. Several specific SMT objectives have also been satisfied. SMT tests are straightforward and can be understood by operating personnel at the fleet level after a short, formal course at Radiomen "B" School. To a large extent, existing test equipment can be utilized. Seven tests permit the entire communications system to be examined. Test sophistication is placed in the test equipment, not in its operation or in the technicians. SMT test sequence can be applied to any communications system, afloat or ashore, unaided.

During December, 1972 the USS Constellation (CVA-64) was used for a demonstration and some of the test results are presented here. All communication systems available for operation were tested. Several significant problems uncovered were corrected or brought to the operator's attention. Noteworthy are the facts that:

1. The SMT disclosed severe maladjustments and failures not discernible by other test methods and
2. The time taken to accomplish the tests was conservatively less than five percent of that required by more conventional means available to the ship personnel.

Problems encountered which could be corrected by adjustments and/or alignments were corrected. Problems requiring maintenance or repair were explained to cognizant, responsible personnel.

It must be pointed out that the test sequence permitted testing of parameters not testable by other methods and that the results were able to point out pieces of equipment which were functioning but operating out of specifications. [38]

Table 5-8 is an example of the SMT TTY test. After the page printers were checked, the alternate channel convertors for the "P" system (UCC-1 channels 1 to 16) were tested and 6 out of 8 were found in need of maintenance. All "n" system channels (low tones) were adjusted and their performance was greatly improved after the SMT tests pointed out weaknesses. A total of 23 transmit and receive multicouplers were tested. Ten of the 23 were found to be out of specifications. Twenty-one HF voice receivers were tested, operating in upper side band (USB), and 4 were found in need of maintenance. Twenty-one UHF voice receivers were tested and 12 "fair" or "poor" performing units were found. Eighteen UHF transmitters were tested and 6 were operating within

SMT TTY TEST

End equipment tests (TTY's and Page Printers) were performed 11 and 12 December 1972. Eight of the best operating machines were selected as reference standards for all other HF record circuit tests.

All types of TTY distortion were introduced to each machine (eight at a time) in 5% increments, until the stress point of each machine was reached. A machine is considered to be in excellent operational condition if it can accept 40% distortion and print clean copy; 35% distortion input with clean copy is considered good; 30% fair; 25% marginal and 20% or below to be operationally in poor condition.

Results of these tests were:

Machine	Max. Distortion with Clean Copy	Max. Stress Point	Type Distortion at Max. Stress Pt.
LTP-C KYBD	40%	45%	Space Bias
LTP-C RCV	35%	40%	Space Bias
LTP-B KYBD	40%	45%	Space Bias
LTP-B RCV	No test - Machine would not space		
LTP-PE KYBD	45%	45%	1 hit on Mark Bias
LTP-N4 PP	40%	45%	Space Bias
LTP-PF KYBD	40%	45%	Mark End
LTP-N3 PP	35%	40%	Mark End
LTP-PD KYBD	35%	40%	Mark Bias
LTP-A KYBD	30%	35%	Mark Bias
LTP-A RCV	35%	40%	Mark Bias
LTP-N1 PP	40%	45%	All
*LTP-PG KYBD	35%	40%	Space Bias
*LTP-N2 PP	35%	40%	Mark End
LTP-N5 PP	35%	40%	Space Bias
LTP-N7 PP	35%	40%	Space Bias
LTP-TC1 PP	30%	35%	Mark Bias
LTP-PB RCV	40%	45%	Space Bias
*LTP-PC KYBD	35%	40%	Mark End
LTP-PC RCV	45%		1 hit on Space End
LTP-PB KYBD	35%	40%	Mark Bias
Metro CH #8	25%	30%	Mark Bias

*NOTE

LTP-PG	KYBD	Margin adjustment required - 3 characters short
LTP-N2	PP	Spacing and line feed problem
LTP-PC	KYBD	Margin adjustment required - 2 characters short

[38]

Table (5 - 8)

specifications. Seven HF transmitters were tested and none were found to be operating within specifications. [38]

E. PROBLEMS WITH PRESENT PROGRAM AND AREAS FOR FURTHER STUDY

1. The SMT program has completed some system and subsystem feasibility studies and needs to devote additional attention to its final two levels of testing, i.e., equipment and circuits.

2. Once laboratory procedures and instrumentation requirements have been established alternate, suitable, test equipment must be examined and a trade-off analysis conducted between equipment cost and equipment capability in order to reduce the price of each set of test equipment from $48,000 to the stated goal of $5,000 per set, while still satisfying the mission of SMT. The ideal cost effective solution, and one which certainly is feasible is to determine what pieces of test equipment, presently in the Naval inventory, could be used to perform the SMT test and thereby not incur any additional equipment expense. The goal should be: that by providing a trained radioman the tapes, he could conduct the test at no additional expense to the Navy other than the cost of his training and the tapes.

3. If the fleet is to be the ultimate user of SMT, the fleet must have trained personnel available which implies a training program, syllabus for SMT and instructors, etc. These needs must be planned for as long lead time items so they can be available when SMT is vailable for fleet use.

4. One of the goals of the SMT program is to replace several less efficient tests presently being used. These tests and/or procedures which are no longer needed must be identified and removed from the inventory. The SMT program should be able to pay for itself with tests, equipment and training it replaces while at the same time it enhances the tests which it complements.

5. The SMT program must keep in mind its long range goals and specific objectives and continue to devote its attention in these areas. Work with the fleet should be secondary to these goals and objectives until the total package is prepared. By dividing its attention between program development and fleet applications it will most likely result in a less efficient product and it will extend the development phase longer than would be otherwise necessary. These detractions must be weighed against possible benefits of present fleet utilization.

6. When Naval Electronic Systems Command has completed the SMT development program, it must have prepared an implementation plan or OPORDER to introduce its technology to the fleet. The transfer of technology, to be effective and fully utilized, must be prepared, programmed and conducted in a well planned and executed maneuver.

7. Once SMT testing procedures for communications System, Sub-system, equipment and circuits have been designed, an adequate level of testing at each level must be developed. The depth, intensity and frequency of tests for components

and systems must be determined. The areas of degraded mode (total systems degradation or component failure which requires use of an alternate procedure) and systems sensitivity to atmospheric or operational phenomena must be determined.

8. Studies must be conducted to determine the time period a calibrated (SMT tested) system remains in calibration. In order to ensure optimum systems availability should the system be tested daily, weekly, once a quarter, etc.? Once this "validity interval" is known an implementation program must be drawn up which would select either or both of the following courses of action:

1) If the validity interval is determined to be measurable in extended periods of time (month or more) the SMT test sequence could be administered to a ship as part of its regular overhaul, pre-deployment ORI, or during every in-port period. This approach would dictate mobile teams stationed in key domestic and foreign ports.

2) If the validity interval is measurable in hours, days or weeks it may be desirable to have each major operating unit able to test itself on a frequent schedule. This approach would permit a ship to continuously monitor its communication system and achieve maximum availability. This solution would be expensive in terms of manpower, equipment and training.

A trade-off analysis should be conducted between the resultant availability and cost.

It may be determined that the optimum solution is a blend of the two approaches with major ships carrying its own SMT equipment while mobile teams provide periodic readiness inspections. Once either or both alternatives is selected, implementation plans must be prepared and funding sought to accomplish the established goal.

9. Voice measuring systems must be refined. The present procedure calls for looking at three 100 Hz windows in the voice band from 200 to 6100 Hz and correlating the data to determine intelligibility. Studies must be continued to determine the optimum location of the three windows and to refine the procedure.

10. Studies must be conducted to determine the signal reproduction loss due to multipath reception and the effect of quad diversity upon the UCC-1.

11. Cross talk between systems and components must be studied so that its effects can be predicted, tested and corrected.

12. Studies of compatibility of the SMT procedures and Secure systems must be conducted. Until Secure systems can be incorporated into communications systems test sequence the sequence will not be able to realize its full potential.

13. The validity of the atmospheric test must be increased. This can be accomplished by improving the atmospheric simulation techniques.

VI. POTENTIAL BENEFITS AND APPLICATIONS OF SMT

The potential applications and benefits to be derived from applications of the SMT concept are numerous. The benefits include increased standardization, more definitive specifications for procurement, reduction of communication systems duplication, reduced manpower needed to support communications, increased availability and a means to measure the degraded level at which a system is operating. Numerous potential applications are also listed.

A. POTENTIAL BENEFITS OF SMT

Standardization is one of the basic principles upon which the SMT concept was founded and it is the key to the high degree of success that has been achieved during the initial phase of development. The standardization principles employed in the development of the SMT concept should also be applied to the development of new equipment by Navy laboratories and commercial contractors to ensure that the same techniques are used to establish performance standards. Standards of performance, based on SMT requirements, should be an integral part of a system, sub-system, equipment and component design specifications. All equipment procurred, as a result of a production contract, should comply with the performance criteria established by SMT as the minimum acceptable for use in an operational environment.

As a result of the use of SMT procedures in evaluating systems performance, standardization of test procedures would be universal regardless of the system configuration or site location. Any manager, operator, or supplier should be aware of the benefits of standardization.

When the operators and industry engineers select a common unit of measurement, as the EDR, RLMG and SMT procedures can provide for communications, everyone will speak the same language. Definitive specifications can be stated, and understood and construction can be monitored in terms of quantified parameters, not qualified criteria as is often the practice at present. The operator can plan on achieving and holding a performance level, which will permit him to make meaningful judgments as to his needs and capabilities.

Once a common unit of measurement has been selected all communications systems can be compared and contrasted with each other. It is quite certain that duplication of communication systems exists between members of the Armed Forces, numerous other government agencies, and within industry. Duplication is taken to mean two systems which perform the same task or similar tasks and for which research and development costs, learning curve costs and implementation costs were duplicated. If all concerned agencies had used one measurement scale it would have been possible to prevent the needless additional expense of developing and/or building and/or introducing the same system twice.

With a test procedure such as SMT, communications systems manpower requirements could be reduced in several ways. Since an entire external communications system can be checked in 5% to 20% of the time needed by present test procedures, less personnel are needed to perform the tests. Less down time is needed to perform maintenance. Systems and components can be tested while installed which means equipment does not have to be removed and replaced and it is not exposed to damage while handling. Additionally, only defective components need be removed and a better indication of the failure can be provided greatly easing the maintenance requirement which means less personnel are needed to perform overhaul or depot level maintenance.

The SMT testing procedures will enable the user to determine the level of performance of his system. The user will be aware of any degradation of the system's performance. He will be able to measure the level of degradation and make a decision, based upon quantitative information, regarding his ability to complete an assigned mission.

Proper utilization of the SMT techniques will increase the communications systems availability. Since availability can be achieved through maintainability and maintainability needs an adequate test procedure and SMT is, not only, an adequate test procedure, but an improvement over any other available test procedure, system availability will increase which means the system operator and user will derive a benefit from utilization of the Standard Measurement Technique. Since

SMT measures degraded mode operations, maintenance can be planned in anticipation of a catastrophic failure which means the system should not, as often, suddenly be put out of commission. When catastrophic failure does occur, SMT will permit quicker trouble shooting and permit a faster restoration of the failed system or component.

Numerous additional benefits may be derived by implementation of SMT. When a garbled message is received, the receiver could test his system to ensure it is operating within specifications. He could inform the sender of the garbled message and the sender could do likewise. It may even be advantageous to have the SMT test signal broadcast from one unit to another in order to test the communications system on a macro level.

An individual unit could introduce a series of messages into its own receiver system and then observe how the messages are handled by its local message distribution system.

Taking this idea one step further could enable SMT to make its greatest contribution to Naval Communications. Since SMT can measure the level of performance of a communications system, as on a ship, and assign a quantitative value to it, it could assign a quantitative value to a total ship's communications suit by testing all on-board communications systems and summing their level of performance. A method of weighting the various systems would have to be devised. In this manner it could be stated that ship X can communicate with a; Y (30%), level of distortion with a Z; (95%), confidence

interval. Once this is done every ship in the Navy could have a quantitative value (s) assigned to its communications suit. Weak performers could receive more attention and strong performers checked to see what beneficial practices could be utilized by other vessels. The same concept could be applied to all Naval Communications Stations whereby their ability to communicate could be quantified. Once ships and stations levels of performance have been determined the test could be applied from the communications stations to the ship and vice versa by transmitting the test tape. This step would enable the performance level of the trunk to be quantified.

Up to this point we have addressed equipment orientated applications. It is possible to include personnel, message handling, distribution and management. By using test tapes with a pre-determined sequence of messages introduced at the communications station, the flag ship, or at an individual ship's receiver, the ability of a communications system to put a message in the hands of the ultimate, intended user could be evaluated. This tape could include messages dealing with operations, administration, supply, etc., and range from FLASH to ROUTINE in priority. In this manner, all aspects of the total communications system, i.e., equipment, personnel, management, etc., could be tested and weak points identified. The test could be repeated at any location or unit and permit a valid, equal comparison between two or more communications systems.

Test tapes could be transmitted via satellite in order to determine the level of performance at which various satellite channels are operating.

Since there is no major communications system test available, SMT would complement present sub-system and component tests. Some tests will be redundant and no longer needed and they can be removed from the inventory producing a cost savings. However the two primary benefits of SMT must not be overshadowed. First it is a means to check a communications system, not components, and secondly it provides a means to measure degraded performance. Since very few systems are operating at full performance levels, an ability to measure the degraded level of performance is necessary.

Retrofit installation of a system and/or equipment is an expensive process. The early acceptance of SMT as a standard installation for new construction could result in a considerable savings. As an interim measure, consideration should be given to the installation of sensors required for SMT in new construction pending a decision to include SMT in initial outfitting.

B. POTENTIAL APPLICATIONS OF SMT

The potential application of Standard Measurement Techniques (SMT) to electronic systems, other than afloat/ashore communication systems, is based on the documented successful achievement of initial objectives obtained in the development of SMT as an integral part of the Navy's overall System Performance Measurement Program.

The application of the SMT engineering concept to the communication links of Tactical Data Systems such as NTDS, ATDS, and MTDS, is a natural extension of the initial application of SMT. Testing hardware in TDS equipped aircraft (E2C, P3C, F14) using real world, simulated inputs, and employing SMT procedures for determining the performance of data links prior to being airborne, would be valuable. The SMT concept could also be employed while airborne to monitor data link performance, determine source of data link problems (own aircraft or termination station), and isolate equipment that is operating below established performance levels.

The techniques of SMT are universal in application to electronic systems. Although, the initial application is for testing naval communication systems, SMT is applicable to:

a. Tactical Data Systems

b. Avionic Systems

c. ASW Systems

d. Weapons Systems

e. Interior Communication Systems (ICS)

f. Command and Control Systems

g. Navigation Systems

h. Aircraft Voice Systems

i. Submarine Communications Systems

j. ECM Systems

Plans have been drawn up to "Hard Wire" the SMT system into the communications system of the USS NIMITZ (CVAN-68) [23] and into the Patrol Frigate (PF) class which is in the development stage [39].

VII. CONCLUSION

The need for a Naval Communications System Level Test Procedure exists. Until this need is satisfied, personnel operating the system will not know or be able to use all the potential of the system which they are working with. Once the level of performance of a system can be quantified, using meaningful criteria, such as, the amount of degradation which it can accept and still be usable for communications or what percentage of the system is operating above a predetermined level, the managers of the system can determine how much through-put the system can provide. This knowledge, capability and availability, is the first step towards efficient utilization of present and future resources. A test procedure is needed which can provide this knowledge.

It has been shown that all existing test procedures are inadequate and mislabeled. Virtually all are called systems level test procedures when they are really subsystem level procedures measuring output power, percentage modulation, etc.

A system level test procedure should be able to accomplish the following:

1) Quantify the level of performance of the system or determine the present level of degradation at which the system is operating.

2) Determine how much degradation in the input signal a system can accept and still put out an error-free or acceptable copy.

3) Determine the communications system ability to communicate; its reason for being.

The Standard Measurement Technique (SMT), presently under development by the Naval Electronic Systems Command, Southwest Division, is a system level test which can fulfill this need. By inputing signals of known degradation and quantifying the output it can measure the ability of a system to pass information. However, SMT is not an end-all. It does not provide all the information which a manager needs in order to operate his system. It should be used to compliment some present subsystems level procedures while others should be deemphasized. SMT can be an excellent tool in the hands of the operators and when used in conjunction with QMS can provide a complete, instantaneous systems status report. It can be used to point out where the maintenance effort should be applied. PMS/3M and Pomsee should be applied as maintenance procedures to failed components located by SMT and QMS.

SMT development, by Naval Electronic Systems Command, must be completed. Alternate cost effective pieces of test equipment must be found. Test procedures must be firmed and alternative applications must be examined. The SMT validity interval needs to be determined so that a decision can be made which will evaluate the costs and benefits of applying SMT to operational units on a periodic schedule, such as once a quarter or before a cruse, or having it built into all units so it can be used continuously.

The Standard Measurement Technique has the potential to deliver system level testing and provide Naval Communications with a complete, true, system, integrated test structure.

APPENDIX A

Major Test Equipment Functions

The functions of the major test equipment used in the "P" system test are as follows:

a. Magnetic tape deck and interface buffer used to input prerecorded standard test message tapes.

b. Spectrum Analyzer is used to measure the individual channel levels of a composite tone, i.e., distortion levels, inter-modulation.

c. Dummy load to absorb the full power transmit signal to acceptable testing levels.

d. Attenuators used to reduce the receiver input voltage levels to acceptable testing levels.

e. Micro-voltmeter used to measure voltage level at receiver.

APPENDIX B

SMT TEST EQUIPMENT LIST

Model Number	Description	Approx. Price
8553B Option-E30	Spectrum Analyzer w/Transit Case	$ 10,625.00
8556A	Plug-in Audio Frequency Spectrum Analyzer	1,690.00
8554L	R. F. Plug-in 1-1.2 GHZ	3,500.00
8444A	H. F. Tracking Generator w/Transit Case	2,950.00
8660A Option-001 Option-003	Synthesizer Signal Generator High Stab. Int. Ref. & Tran. Case 50-400 HZ Power	5,257.00
86601A	R. F. Section .1-110 MHZ	1,977.00
86632A	AM/FM Modulation Section	900.00
11661A	Frequency Extension Moduls for 8660B/86602A	2,000.00
86602A	R. F. Plug-in Section 1-1300 MHZ	2,800.00
8721A Option-H01	Directional Bridge (100KHZ-110MHZ) (2W) (2 ea)	602.00
1778D	Directional Bridge (100MHZ-2000MHZ) (2 ea)	900.00
10514A	Double Balance Mixer	90.00
BIRD	Inline Wattmeter/Coupler	780.00
355C	Attenuator	160.00

APPENDIX B (Continued)

Model Number	Description	Approx. Price
355D	Attenuator	$ 160.00
3960G Option E0-1	Tape Recorder	160.00
13063A	Amplifier	
13066A	Transit Case	4,620.00
- - - -	Interface Kit built by P. M. R.	2,000.00
3555B	Noise Measuring Set	688.00
Tapes	200 @ $25.00	5,000.00
H04-3550B Option H04	Transmission Line Test Set	1,809.00
		$48,508.00

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ABSTRACT

Several recent studies of Naval Communications have determined that the system is not operating properly. This paper presents a test procedure which will improve the performance of the equipment that composes the Communications System. The need for a test procedure, modes of failure and present test procedures are examined. It is determined that present test procedures referred to as system level tests are mislabelled and are actually subsystems level tests. A Systems Level Test, the Standard Measurement Technique (SMT) which applies inputs of known degradation to a system and quantifies the output is presented. Present problems and potential applications of SMT are discussed.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
COMMUNICATIONS						
SYSTEM TEST PROCEDURE						
STANDARD MEASUREMENT TECHNIQUE						

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